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THE WELDING JOURNAL

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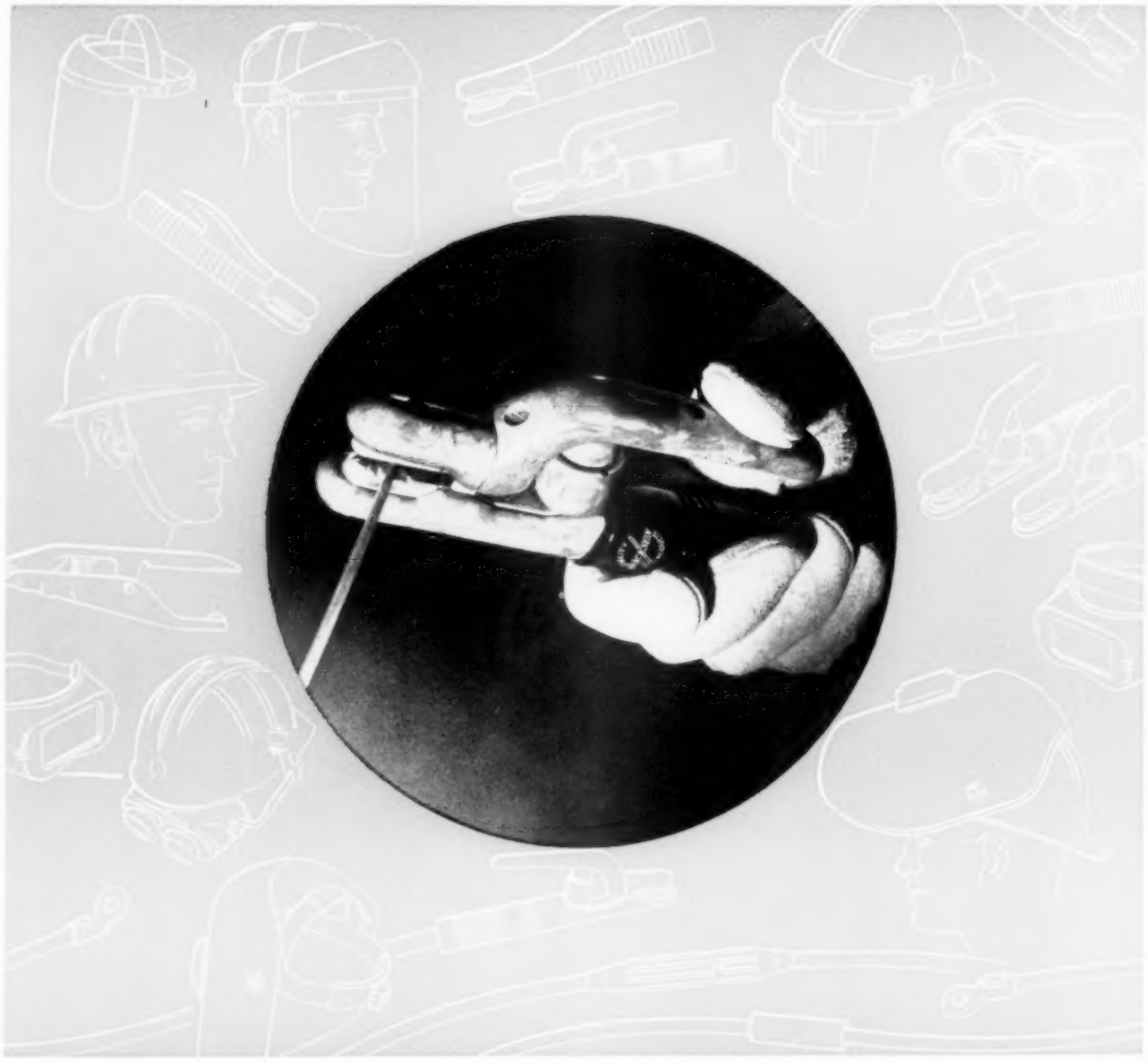

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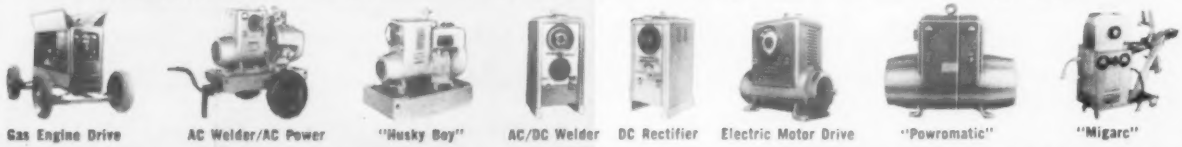

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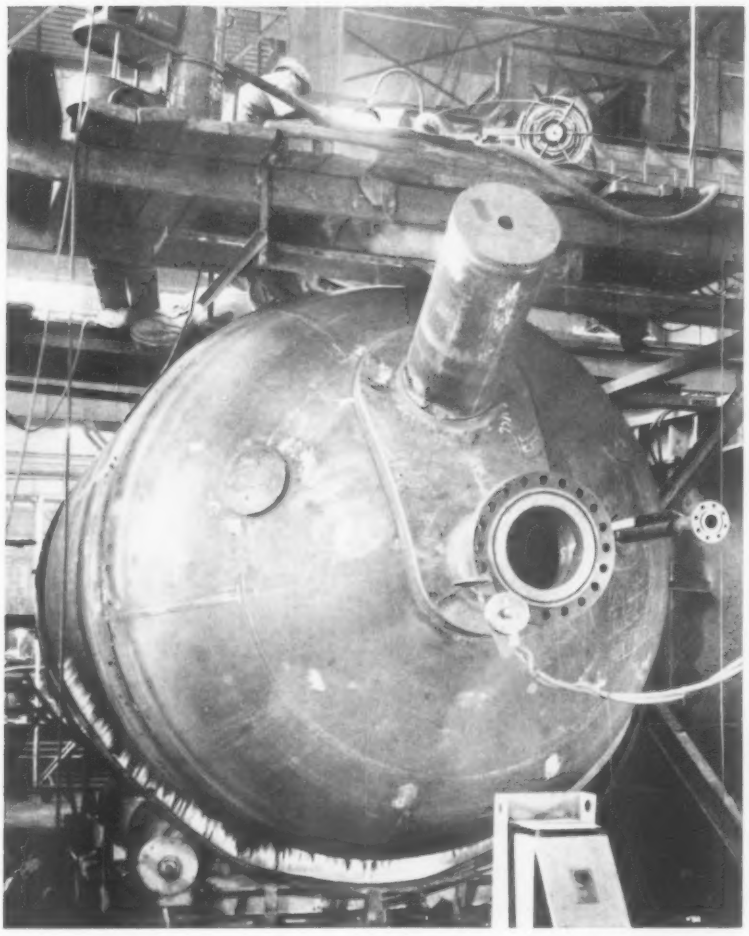

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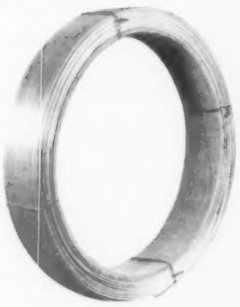

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TO BE GRATEFUL

Many prayers end with: "and teach us to be grateful." It seems strange that a person has to be taught to be grateful. Perhaps it is because so many are born with so much, or are given so much without effort that they have no sense of gratitude, but come to believe they are entitled to things without thought of others.

There is much evidence every day that the world is suffering from a lack of gratitude. Actions indicate that things for which people and nations once were grateful, today are expected as standard bill of fare with only an outward show of disgust and arrogance when it is not forthcoming.

There are many things for which a person can be grateful. Environment, station in life and intelligence intermingle with each of our emotions and experiences to cause a feeling of gratefulness. This does not mean one has to be highly intelligent or worldly to partake of this God-given means of expression. It comes to one and all. Oftentimes it is only a fleeting smile passed from a recipient; or a voice simply saying "Thank you," and meaning it.

I am sure that if there were an unbridled expression of gratefulness in this world today between people, between nations, between races, and yes, just between me and thee, there would be little need for a United Nations, cold wars, hot wars, Iron or Bamboo curtains.

We fortunate individuals in the welding industry have much for which to be grateful. Our challenge is ever changing, never ending. Each year unfolds new methods, new processes that further integrate us into all industry. Our processes can take credit and blame for the benefits and horrors they make possible. If only man's ingenuity could be blended with an expressive gratefulness to all peoples of the world, then we could say we were using to the fullest our God-given blessing to exploit our chosen field.

We mortals have much to be grateful for and many to be grateful to. Let our words be transmitted to deed and action on every turn. That alone will teach others to be grateful.

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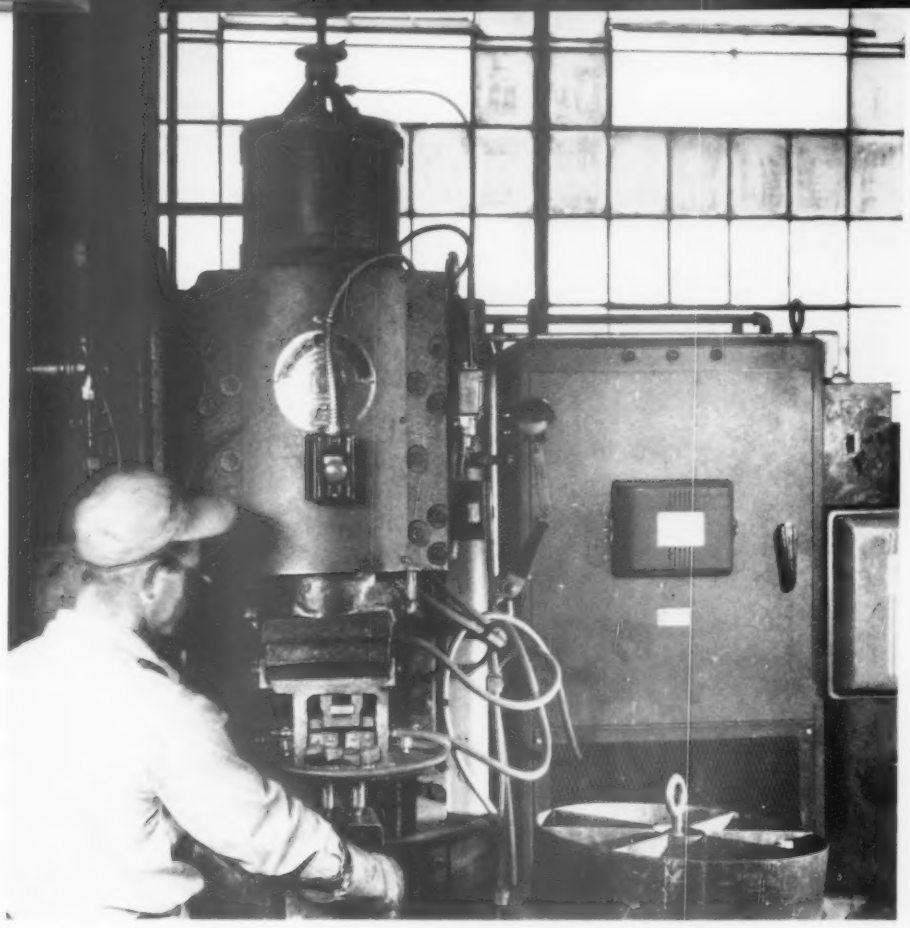

250-kva projection welder in operation

SCHEDULES FOR SPOT WELDING PROJECTION HARDWARE TO MILD-STEEL SHEET AND PLATE

Electrode requirements, welding-current values, electrode forces and cycles of weld time that have been experimentally determined for welding a wide variety of hardware-to-sheet-thickness combinations are the principal factors covered by the author

BY O. K. BARNES, JR.

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Paper presented at the AWS 1955 National Fall Meeting held in Philadelphia, Pa., October 17–21.

ABSTRACT. Welding schedules have been developed to provide a ready means of setting up a resistance spot-welding machine to weld any of the numerous types and sizes of projection hardware to low-carbon steel sheet and plate. This paper deals with electrode requirements, welding-current values, electrode forces and cycles of weld time that have been experimentally determined for welding a wide variety of hardware-to-sheet-thickness combinations. Also included in the schedules are weld-strength values obtained by testing welded samples to destruction in a standard tensile-test machine.

A method of using a pointer stop ammeter to set up and observe the secondary welding currents at the necessary levels is described, test methods are outlined, and certain aspects of proper joint design are brought out.

After a spot-welding machine has been set up to weld a given hardware type to a selected sheet thickness, this type may be welded to other material thicknesses by changing the weld-time variable only. With welding current and electrode force established on the machine, the weld time is adjusted to the schedule value shown for the selected material thickness.

Fig. 1 Miscellaneous projection hardware types

Of further interest is the minimum number of electrode combinations and sizes required for all hardware-to-sheet assemblies, thus eliminating the need for a large, specialized electrode inventory.

Introduction

When one considers the large assortment of hardware parts and sizes that are presently being welded by sheet-metal fabricators to eight commonly-used sheet and plate thicknesses, it is seen that an impressive number of hardware-to-sheet-thickness combinations are possible. It is also apparent that establishing reliable welding current, force and time values, along with suitable electrode combinations for each condition, can be somewhat of a problem to the set-up man or welding operator if simplified data is not readily available. Time, as well as material and labor, is lost and welds may be of questionable quality where the necessary information must be gained by cut-and-try methods.

In response to requests from several of our company divisions for information of this nature, a development program was initiated to develop data to meet their specific needs. This program was later expanded to include company-wide applications so that a process specification could be written for general use.

Hardware Types and Classifications

Projection hardware is a generic term referring to the various shapes in the form of nuts, bolts, brackets, screws, weld pads, pins and spacers that are resistance welded to steel sheet and plate by manufacturers of sheet-metal products.

These specialized hardware parts (see Fig. 1) have one or more projections coined or embossed on one of the two main pressure surfaces for the purpose of concentrating the welding current at small interface areas during the welding cycle. As a result, the part is welded to the base material at several points simultaneously.

Projection forms vary with hardware types and sizes. Some projections are dome shaped, others are square or rectangular pyramids; and where a pressure or vacuum-tight weld is specified, a ring projection is used to produce a circumferential weld or hermetic seal.

For this investigation, all hardware types have been classified into two groups, according to the electrode setup requirements. Group I includes all weld pads, nuts, spade bolts and other items having two main parallel pressure surfaces, and which can be welded with two flat-face electrodes. In Group II are all items with portions extending beyond the main parallel pressure surfaces. Typical examples are the pins, bolts, screws and studs with projections on top of or under the head, and are welded with one recessed and one flat electrode.

This grouping makes it possible to standardize on a minimum number of electrode combinations required for welding a maximum number of hardware-to-thickness combinations. Figure 1 illustrates a few of the many hardware types available for welding to sheet-metal components. Both Group I and Group II items are represented here. Flat items of Group I classification are seen in the right foreground.

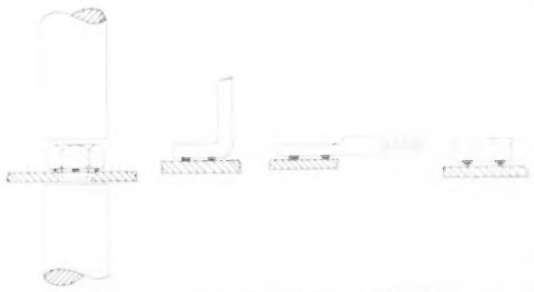


Fig. 2. Flat-face electrodes and Group I hardware types

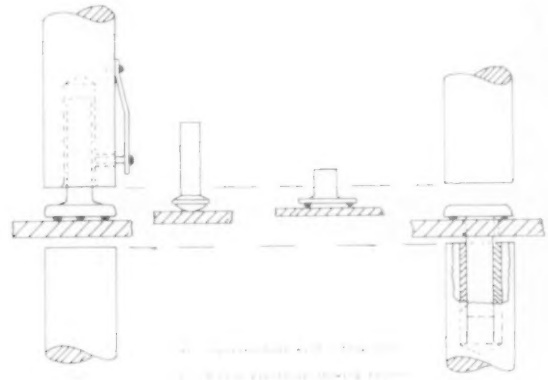


Fig. 3 Recessed electrodes and Group II hardware types

Electrode Types and Sizes

Figure 2 shows the electrode setup for welding hardware in the Group I classification.

The "D" diameters of all electrodes are indicated in the schedules for each item. The hex nut between the electrodes is the self-locating variety shown positioned for welding.

Figure 3 shows the combination of one flat and one recessed electrode for welding parts in the Group II classifications.

In this figure (a) is a spring-pin arrangement for holding the hardware part until it is positioned on the work. At (b) in this figure, the lower electrode is shown recessed to take the weld pin. Insulation is provided in the recess to prevent current shunting through the pin during the welding cycle. The two hardware parts near the center are other examples of Group II items.

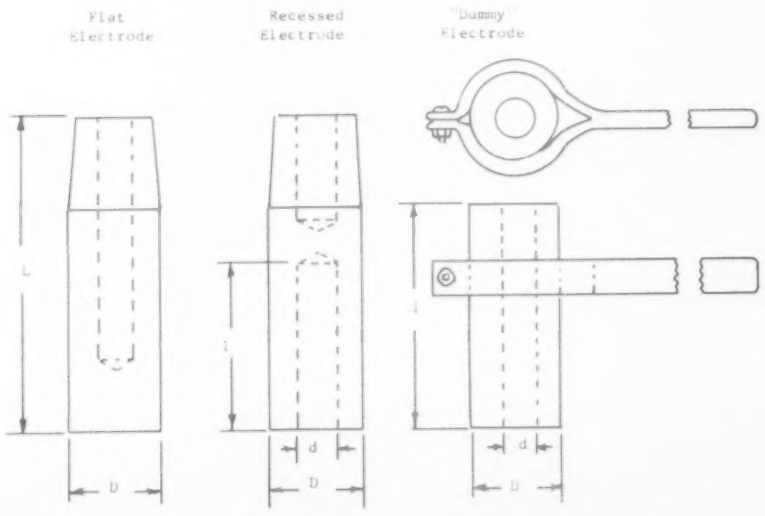
Figure 4 shows standard electrode sizes and types, identified by number according to the "D" diameter and "L" length. The recessed electrode hole dimensions are designated by capital letters and are shown in the table at the top of this figure. These letter designations appear in the schedules for each hardware part requiring a recessed electrode.

When regular fixtures are not used to position the hardware, a "dummy" electrode is sometimes used. This is provided with a handle for placing the part for welding and also permits the electrode to be cooled in a

Fig. 4 Flat and recessed electrodes and "dummy" electrodes for welding Group II hardware items. Also shown is a table of letter designations for the hole sizes of recessed and "dummy" electrodes

Electrode Recess	Hole Size Designations										
	A	B	C	D	E	F	G	H	J	K	L
d - diameter	.170"	.196"	.222"	.250"	.280"	.312"	.350"	.407"	.425"	.532"	.657"
l - length	1/2"	7/8"	1-3/8"	1/2"	2-1/4"	1-3/8"	1-3/8"	2"	1"	2-1-8"	3/4"

Electrode No.	D Dia.	L Length
1	5/8"	3"
2	7/8"	3"
3	1"	3"
4	1-1/4"	3"



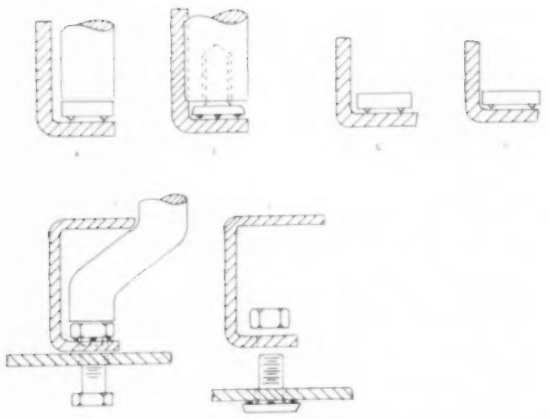


Fig. 5 Hardware-to-plate assemblies. Proper and improper joint designs

container of water between welding operations. Dimensions of the "dummy" electrode are governed by the size of the part to be welded. An example of this electrode type is shown at the right in Fig. 4. All electrodes are of R.W.M.A. Class II material and are water cooled. "Dummy" electrodes are placed in a container of water while workpieces are being positioned in the machine.

Hardware-to-Flange Designs

When designing a product in which projection hardware elements will be used, the design engineer should familiarize himself with the assembly details and the steps to be followed in attaching the various parts. If he is able to visualize the electrode setup required for welding each component, he can allow sufficient flange widths and edge distances, and will specify ample clearances.

Many of the problems encountered in production welding today could be eliminated by a close working arrangement between the design and the production departments.

Figure 5 shows several simple illustrations of good versus poor joint designs.

In this figure, A shows an arrangement with adequate electrode clearance. Assembly B is an example of insufficient flange width allowed for the electrode size specified in the schedule for this particular item. The dotted line shows the extent of the interference between the electrode and the vertical portion. To correct this condition, a wider flange could be used, or a part requiring a smaller diameter electrode could be substituted for the size shown here.

The assembly at C in this figure is a structural member wide enough to accomodate the hardware part. The assembly shown at D illustrates insufficient flange width to maintain the proper edge distance.

Welding the part in this position would result in weld-metal expulsion, since the outer projections are too near the edge of the workpiece.

The arrangement at E in Fig. 5 is a self-locating hex nut positioned in a hole for welding to the channel member. The lower plate and bolt are shown merely to illustrate how the two structures will be bolted together after the projection nut is welded in place. It is not intended to show the parts in position for welding.

With the electrode arrangement at E, insulation would be required to prevent current shunting through the structural part where it contacts the electrode. This insulation would have to be replaced frequently because of the severe cutting action of the channel edge at the contact point. With a welding force of fifteen hundred pounds indicated in the schedules for this hardware-to-sheet combination, the use of offset tips would not be recommended for this application. A "dummy" electrode would be placed between the nut and the top leg of the channel and the parts then welded with in-line electrodes.

The alternate assembly shown at F illustrates how a different hardware part is selected to simplify the welding operation and meet the bolted joint requirement. A weld bolt having projections under the head is passed through the hole and welded to the bottom plate. The two members are then bolted together, thus eliminating the need for welding the hardware part to the channel member. By merely substituting a different hardware item and welding to the opposite assembly member, the electrode setup is simplified. The examples illustrated in this figure are elementary, but serve to point out the value of proper part selection when designing for welding.

Welding Schedules

The data sheets presented as Tables 1 to 21 are arranged to provide the necessary information for welding the hardware parts illustrated and identified by name in the first column at the left of the table.

The second column shows the diameter and thread or the dimensions of unthreaded types.

The third column gives the sheet and plate thicknesses to which the item is welded, and represents maximum and minimum application limits.

The fourth column indicates the types, sizes and combinations of electrodes to be used for the various hardware-to-sheet-thickness combinations. The hole sizes of recessed electrodes are indicated where this type of electrode is required to weld a Group II item.

Weld pressures or net electrode forces are given in column five. These are set up on the machine by using a force gage, or by using force calibrations from a chart posted on the welding machine.

The weld time determined for each hardware-to-sheet-thickness combination is given in the sixth column from the left. This is the only variable that is changed when welding a specific hardware part to different sheet thicknesses.

The seventh column shows the secondary welding current required to weld the part to the thickness range shown in the third column.

The short-circuit current through copper is given in column eight. This current value is used when setting

Table 1—Schedule for Weld Bolts

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Ckt. Current Thru Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Bolt	.190-32	.028	No. 1	1000	5	21,000	27,000	10	
	.250-28	.036		1000	10	19,500	25,000	15	
	.312-24	.059		1400	10	21,000	27,000	15	
	.375-24	.075	"R" Style Dome	1800	10	21,000	27,000	15	
	.437-20	.090		2000	10	21,000	27,000	15	
	.500-20	.105				.250			
	.562-18	.120		2400	10	21,000	27,000	15	
	.625-18	.135	No. 2	2700	10	21,000	27,000	15	
	.750-16	.165		3200	10	21,000	27,000	15	
	.875-14	.190		3700	10	21,000	27,000	15	
	1.000-13	.220		4200	10	21,000	27,000	15	
	.190-32	.028		1400	5	23,000	29,000	10	800
	.250-28	.036	No. 3	1500	10	23,000	29,000	20	1200
	.312-24	.059		1800	10	23,000	29,000	20	1600
	.375-24	.075	"R" Style Dome	2200	10	23,000	29,000	20	2000
	.437-20	.090		2500	10	23,000	29,000	20	2400
	.500-20	.105		2800	10	23,000	29,000	20	2800
	.562-18	.120		3200	10	23,000	29,000	20	3200
	.625-18	.135	No. 4	3500	10	23,000	29,000	20	3600
	.750-16	.165		4000	10	23,000	29,000	20	4000
	.875-14	.190		4500	10	23,000	29,000	20	4000
	1.000-13	.220		5000	10	23,000	29,000	20	4000

Table 2—Schedule for Watertight Weld Nuts and Square Weld Nuts

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Ckt. Current Thru Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Water Tight Weld Nut	.138-32	.028	No. 1	1000	5	21,000	27,000	10	All welds were not tested. No leaks in samples tested. Tensile test in excess of 3000 lbs. per sq. in.
	.164-32	.036		1500	10	21,000	27,000	20	
	.190-32	.059		1800	10	21,000	27,000	20	
	.217-32	.075	"R" Style Dome	2200	10	21,000	27,000	20	
	.250-32	.090		2500	10	21,000	27,000	20	
	.280-32	.105		2800	10	21,000	27,000	20	
	.312-32	.120		3200	10	21,000	27,000	20	
	.375-32	.135	No. 1	3500	10	21,000	27,000	20	
	.437-32	.165		4000	10	21,000	27,000	20	
	.500-32	.190		4500	10	21,000	27,000	20	
	.562-32	.220		5000	10	21,000	27,000	20	
	1/4-32	.036	No. 3	2000	5	37,000	43,000	20	3200
	5/16-32	.059		2400	10	37,000	43,000	20	3600
	3/8-32	.075		2800	10	37,000	43,000	20	3600
	7/16-20	.090	"R" Style Dome	3200	10	37,000	43,000	20	3600
	1/2-20	.105		3600	10	37,000	43,000	20	4000
	9/16-18	.120		4000	10	37,000	43,000	20	4000
	5/8-18	.135	No. 3	4500	10	37,000	43,000	20	4000
	3/4-16	.165		5000	10	37,000	43,000	20	4000
Square Weld Nut	1/4-20	.036	No. 2	1500	5	21,000	25,000	20	2000
	5/16-18	.059		2000	10	21,000	25,000	20	3000
	3/8-16	.075		2500	10	21,000	25,000	20	3600
	7/16-14	.090		3000	10	21,000	25,000	20	4000
	1/2-13	.105	No. 4	3500	10	21,000	25,000	20	4000
	9/16-12	.120		4000	10	21,000	25,000	20	4000
	5/8-11	.135		4500	10	21,000	25,000	20	4000

Explanatory Notes

NOTE 1. Name and sketch of hardware item are shown in this column to aid in visual identification of part.

NOTE 2. Diameter and thread or overall size is shown to aid in identifying the item size without referring to the drawing.

NOTE 3. Sheet and plate thicknesses represent maximum and minimum application limits. Hardware items may be welded to intermediate thicknesses by using the schedule for the nearest thickness in this column.

NOTE 4. Electrode combinations show two flats, or a recessed dummy electrode and two flats. The use of a dummy electrode is optional and one flat and one recessed electrode may be used in high-activity applications. Dummy electrode is provided with a handle for positioning for welding and water cooling between welding operations.

NOTE 5. Welding force is the net electrode force measured in pounds exerted on the work.

NOTE 6. Welding current is the secondary current during the actual welding cycle. It is not the same as short-circuit current through copper. Welding current variation should be held to ±5%.

NOTE 7. Short-circuit current through copper is used as an aid in setting up the spot-welding machine to a selected schedule. When set to this value while firing through copper, the machine will be set to delivery approximately the required welding current. Final adjustments should be made on the work.

NOTE 8. Hold time is the time required to solidify the weld under pressure after the welding current has been terminated. This time is set on the welder control.

NOTE 9. Tensile strength values were obtained by pull-out or push-out tests, with samples held in a fixture for tensile load application. Shear strength values were obtained by using a fixture to apply a shear force to the welded sample. All specimens were tested to destruction in a standard tensile-testing machine. High impact strengths were observed when welded assemblies were subjected to hammer blow tests. *It is not intended to indicate that the values shown are maximum strength, but are to be used as a guide only. Different current and time values will produce higher strengths for specific applications.*

up a spot-welding machine to a selected schedule. When set to this value while firing through copper, the machine will deliver approximately the required welding current. Final adjustments should be made on the work.

The hold time required to solidify the weld metal under pressure after the welding current has been terminated is given the ninth column. This is set on the control panel and schedule values should be observed at all times. The use of short hold time can result in erratic and undependable weld-strength values, and often means the difference between a good weld and one of unacceptable quality.

Tensile-strength values are shown in the last or

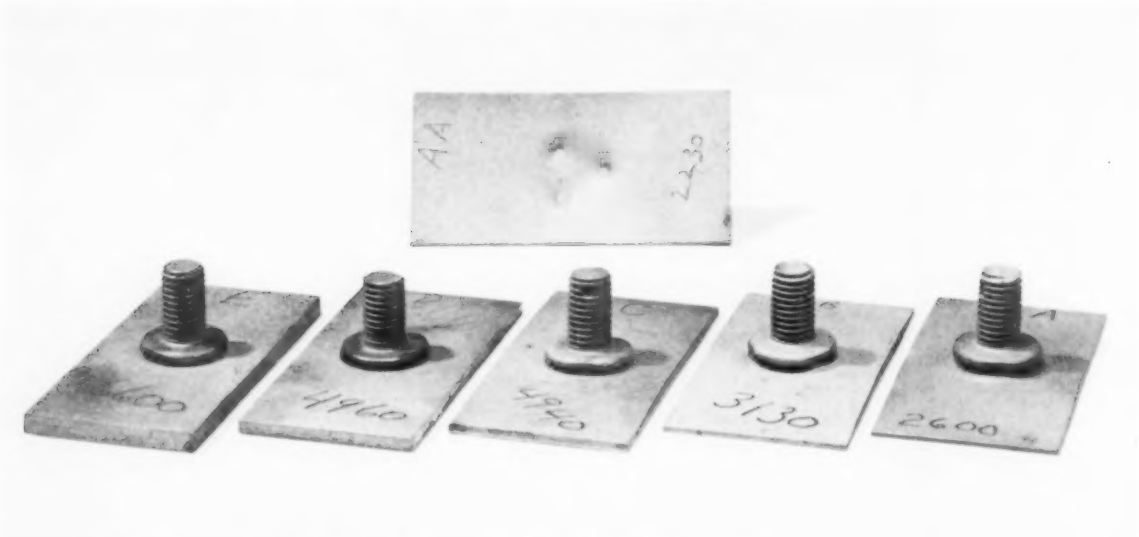


Fig. 6 Specimen welds with a projection bolt welded to various material thicknesses

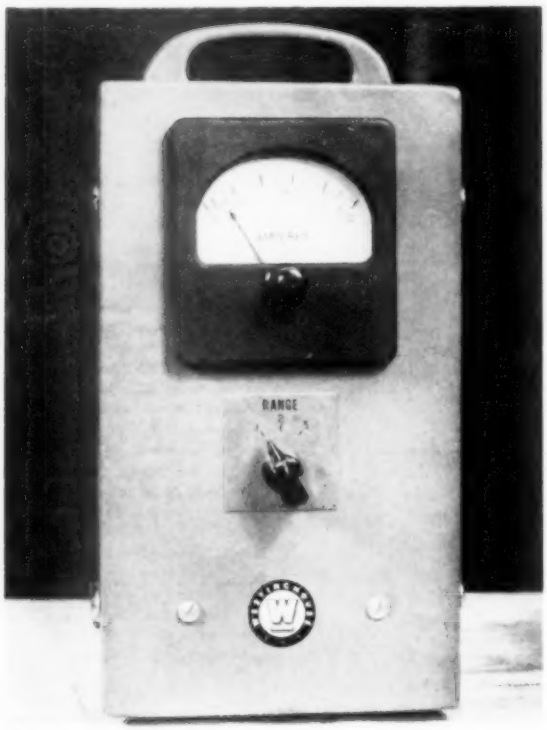


Fig. 7 Current meter

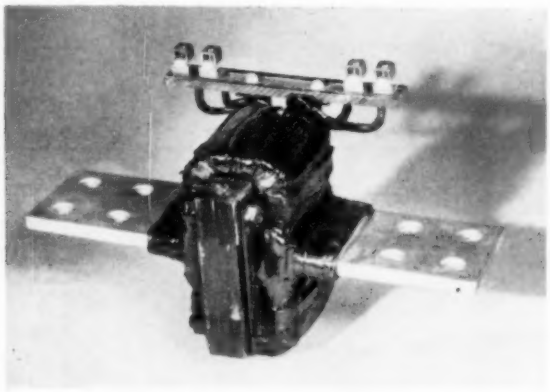


Fig. 8 Current transformer

tenth column, and were obtained by pull-out or push-out tests. Where shear strengths are given, a fixture was used to apply the shear forces to the test pieces. A standard tensile-test machine was used in the pull-out and push-out tests. Impact strengths were checked by hammer-blow tests. When subjected to these destructive tests, failures occurred mainly in the hardware part or in the base material instead of through the weld nugget.

Figure 6 illustrates a weld bolt welded to five different material thicknesses, by adjusting the weld time only for each thickness change. The sample standing on edge shows the opposite side with material failure occurring at three places. This piece is the same thickness as the sample shown at the right. Reading from right to left, material thicknesses and weld strengths are as follows: 0.094 in., 2600 lb; 0.125 in., 3130 lb; 0.156 in., 4940 lb; 0.188 in., 4960 lb; 0.250 in., 6620 lb.

Instrumentation

Welding current and electrode force in a selected welding schedule are set up on a standard resistance-welding machine after carrying out the following preliminary steps:

1. A pointer-stop ammeter (Fig. 7) is mounted on the front of the welder within easy reach of the operator but out of range of the magnetic or inductive loop of the welder transformer. A current transformer (Fig. 8) is installed in the primary side of the welder transformer and connected to the range switch on the meter.

2. A data chart similar to the one shown in Table 22 is prepared for each machine as follows:

a. The turns ratios of the machine transformer taps are obtained from the machine nameplate or from the data sheets supplied by the manufacturer. This information may also be gained by placing a jumper across the ignitron tubes and measuring the open-circuit voltage at the electrodes for each tap setting. Primary-voltage checks are made along with the secondary-voltage measurements, and the individual tap ratios are found by simple calculation.

This information helps determine the size of the current transformer (Fig. 8) that will be required for the meter circuit on each welding machine. To illustrate, a machine with a nameplate rating of 30,000 amp and a voltage ratio of 30:1 on the high tap will require a transformer capable of carrying at least 1000 amp.

Two sizes of transformers are in present use on resistance-welding machines in the various company divisions. Both are applicable on 220-, 440-, 550- and 2300-volt primaries. One size has ratios of 200-400-600 to 5 amp. Ratios of the other size are 300-600-1200 to 5 amp.

With a standard 5-amp meter equipped with a back pointer-stop, either a direct reading scale or a scale reading 0 to 5 amp may be used. When a meter with a direct reading scale is connected to a transformer with ratios of 300-600-1200 to 5, the multipliers for ranges 1, 2 and 3 are 0.5, 1 and 2, respectively.

b. With transformer turns determined and meter

Table 3—Schedule for Weld Screws and Pins

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
[illegible]	[illegible]	[illegible]	No.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	[illegible]	[illegible]	No.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	No.2	1500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	[illegible]	[illegible]	No.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1/2-13	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4—Schedule for Spade Bolts

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Table 5—Schedule for Weld Clip and Pad

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Clip	2x11/32 x3/32"	.064		1500	10	16,000	19,000	20	800
	2x11/32 x3/32"	.078	No.1	1500	10	16,000	19,000	20	900
	2x11/32 x3/32"	.094		1500	15	16,000	19,000	20	1000
	2x11/32 x3/32"	.125		1500	15	16,000	19,000	[illegible]	1000
	2x11/32 x3/32"	.156		1500	20	16,000	19,000	30	1100
	2x11/32 x3/32"	.188	No.1	1500	20	16,000	19,000	30	1100
	2x11/32 x3/32"	.250		1500	25	16,000	19,000	40	1200
Projection Welding Pad	3/8-16	.064		2500	10	37,000	43,000	20	3000
	3/8-16	.078	No.3	2500	10	37,000	43,000	20	4000
	3/8-16	.094		2500	15	37,000	43,000	[illegible]	4000
	3/8-16	.125		2500	15	37,000	43,000	[illegible]	[illegible]
	3/8-16	.156		2500	20	37,000	43,000	30	[illegible]
	3/8-16	.188	No.3	2500	20	37,000	43,000	30	6000
	3/8-16	.250		2500	25	37,000	43,000	30	6000
	1/2-13	.064		2500	10	37,000	43,000	20	3000
	1/2-13	.078	No.3	2500	10	37,000	43,000	20	4000
	1/2-13	.094		2500	10	37,000	43,000	20	4000
	1/2-13	.125		2500	15	37,000	43,000	30	5000
	1/2-13	.156		2500	20	37,000	43,000	30	5000
	1/2-13	.188	No.3	2500	20	37,000	43,000	30	6000
	1/2-13	.250		2500	25	37,000	43,000	30	6000

range multipliers known, the meter readings for specific secondary-current values in the schedules are calculated using the following formula:

$$\text{Meter reading} = \frac{\text{Required Secondary Amperes}}{\text{Meter Multiplier x Welder Trans. Tap Ratio}}$$

Example: To set meter for 26,200 amp

$$\frac{26{,}200}{36.3(*)} = 721\text{-amp primary current}$$

Use range switch on position #3 with multiplier 2

$$\text{Meter reading} = \frac{26{,}200}{2 \times 36.3(*)} = 360 \text{ amp}$$

Set pointer stop for 360

* Turns ratio of welder transformer tap selected for required current output.

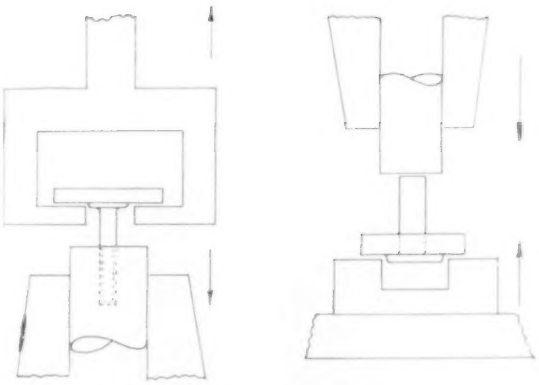


Fig. 9 Sketch of test fixtures used in destructive tests

c. Air-gage pressure settings for the welding forces shown in the schedules are found by placing a force gage between the electrodes and adjusting the air-pressure gage until the force gage registers the desired welding force. The air-gage reading is recorded and other welding forces measured and shown on the machine-data chart.

d. Heat dial settings for set-up currents are determined by setting the pointer-stop, transformer tap and at least ten cycles of weld time on the timer control panel and firing the machine through a piece of copper. By adjusting the heat-control setting until a definite lift of the meter pointer is observed, the approximate % heat control is obtained. After obtaining % heat values for all set-up currents in the schedules, the work of preparing the machine-data chart can be completed.

Destructive Tests

Figure 9 shows the fixtures used in test loading of welded assemblies. All results were recorded, and where strength values were found erratic, the machine settings were adjusted until consistent breaking-load

Table 6—Schedule for Self-Locating Nuts and Transformer Studs

Name & Sketch of Part Note 1	Size or Dia. of Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Tip Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Alloy Note 7	Cool Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Self Locating Nut	1/4-20	.063							
	1/4-28	.078							
	5/16-18	.078							
	5/16-24	.094							
	3/8-16	.125							
	3/8-24	.156							
	7/16-14	.188							
	7/16-20	.250							
Transformer Studs	1/4-20	.094							
	5/16-18	.125							
	3/8-16	.156							
	7/16-14	.188							
	1/2-13	.250							
	1/4-20	.094							
	5/16-18	.125							
	3/8-16	.156							
	7/16-14	.188							
	1/2-13	.250							

Table 7—Schedule for Square Weld Nut

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Tip Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Alloy Note 7	Cool Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Square Weld Nut	.190-32	.031							
	.190-32	.062							
	.190-32	.078							
	.190-32	.094							
	.190-32	.125							
	.190-32	.156							
	.190-32	.188							
	.190-32	.250							
	1/4-20	.031							
	1/4-20	.062							
	1/4-20	.078							
	1/4-20	.094							
	1/4-20	.125							
	1/4-20	.156							
	1/4-20	.188							
	1/4-20	.250							
	5/16-18	.031							
	.164-32	.062							
	.164-32	.078							
	.164-32	.094							
	.164-32	.125							
	.164-32	.156							
	.164-32	.188							
	.164-32	.250							

Table 8—Schedule for Weld Pads

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Cont. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Asbe Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Pad	1/2x1/8 x 1/2x1/8	.032		1200	8	16,000	28,000	10	700
	1/2x1/8 x1/2x1/8	.064	No.1	1200	10	18,000	31,000	10	1000
	1/2x1/8 x1/2x1/8	.078		1200	12	20,000	32,000	10	1200
	1/2x1/8 x1/2x1/8	.094		1200	12	21,000	33,000	10	1300
	1/2x1/8 x1/2x1/8	.125		1200	15	22,000	34,000	10	1500
	1/2x1/8 x1/2x1/8	.156	No.1	1200	20	23,000	35,000	10	1800
	1/2x1/8 x1/2x1/8	.188		1200	25	24,000	36,000	10	2100
	1/2x1/8 x1/2x1/8	.250		1200	30	25,000	37,000	10	2400
	5/8x1/2 x5/16x1/2	.064		1200	10	21,000	33,000	10	1200
	5/8x1/2 x5/16x1/2	.078	No.1	1200	12	22,000	34,000	10	1400
	5/8x1/2 x5/16x1/2	.094		1200	12	23,000	35,000	10	1500
	5/8x1/2 x5/16x1/2	.125		1200	15	24,000	36,000	10	1700
	5/8x1/2 x5/16x1/2	.156	No.1	1200	20	25,000	37,000	10	2000
	5/8x1/2 x5/16x1/2	.188		1200	25	26,000	38,000	10	2300
	5/8x1/2 x5/16x1/2	.250		1200	30	27,000	39,000	10	2600
	11/16x11/16 x1/2x1/2	.078		1200	12	23,000	35,000	10	1500
	11/16x11/16 x1/2x1/2	.094	No.2	1200	12	24,000	36,000	10	1600
	11/16x11/16 x1/2x1/2	.125		1200	15	25,000	37,000	10	1800
	11/16x11/16 x1/2x1/2	.156		1200	20	26,000	38,000	10	2100
	11/16x11/16 x1/2x1/2	.188		1200	25	27,000	39,000	10	2400
	11/16x11/16 x1/2x1/2	.250	No.2	1200	30	28,000	40,000	10	2700

Table 9—Schedule for the Nuts

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Cont. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Asbe Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Nut	.164-32	.032	No.2	1500	8	22,000	26,000	10	400
	.164-32	.064		1500	10	22,000	26,000	20	450
	.164-32	.078	Hole	1500	10	22,000	26,000	20	450
	.164-32	.094	Slot	1500	15	22,000	26,000	30	500
	.164-32	.125		1500	15	22,000	26,000	30	500
	.164-32	.156		1500	20	22,000	26,000	30	500
	.164-32	.188	No.2	1500	20	22,000	26,000	30	570
	.164-32	.250		1500	25	22,000	26,000	30	570
	.190-32	.032	No.2	1500	8	22,000	26,000	20	400
	.190-32	.064		1500	10	22,000	26,000	20	450
	.190-32	.078	Hole	1500	10	22,000	26,000	20	450
	.190-32	.094	Slot	1500	15	22,000	26,000	30	500
	.190-32	.125		1500	15	22,000	26,000	30	500
	.190-32	.156		1500	20	22,000	26,000	30	550
	.190-32	.188	No.2	1500	20	22,000	26,000	30	600
	.190-32	.250		1500	25	22,000	26,000	30	600
	[illegible]	[illegible]	No.2	1500	10	22,000	26,000	20	600
	[illegible]	[illegible]		1500	10	22,000	26,000	20	650
	[illegible]	[illegible]	Hole	1500	15	22,000	26,000	30	650
	[illegible]	[illegible]	Slot	1500	15	22,000	26,000	30	700
	[illegible]	[illegible]		1500	20	22,000	26,000	30	700
	[illegible]	[illegible]	No.2	1500	20	22,000	26,000	30	750

[illegible]	[illegible]	[illegible]	No.2	1500	10	22,000	26,000	20	900
	[illegible]	[illegible]		1500	10	22,000	26,000	20	950
	[illegible]	[illegible]	Hole	1500	15	22,000	26,000	30	950
	[illegible]	[illegible]	Slot	1500	15	22,000	26,000	30	1000
	[illegible]	[illegible]		1500	20	22,000	26,000	30	1000
	[illegible]	[illegible]	No.2	1500	20	22,000	26,000	30	1000

Table 10—Schedule for Watertight Weld Screws

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Cont. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper-Asbe Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Watertight Weld Screw	[illegible]	[illegible]	No.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Hole	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Slot	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	No.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	No.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Hole	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	Slot	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	No.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

values were obtained. In this figure, arrows indicate the direction of load application to the test piece in pull-out and push-out tests.

Conclusions

From the results observed in this investigation, the following conclusions may be drawn:

1. Electrode combinations for welding a wide variety of hardware items have been reduced to a minimum number, making it possible to standardize fewer types and sizes to meet all application requirements. This simplifies the problem of maintaining an adequate electrode inventory.

2. Tested welding schedules provide a dependable means of obtaining consistently sound welds in production runs.

3. Individual projection hardware items can be welded to various thicknesses of low-carbon steel sheet and plate without changing the welding current or electrode-force settings. This is accomplished by adjusting the weld time to the value shown in the schedules for the material thickness used.

4. Overwelding and deforming of threaded portions is avoided by the use of suitable current-force-time combinations for each joint condition.

5. Weld strengths obtained in the development work are reproducible in the shop where varying conditions such as machine size and capacity are encountered. This is accomplished by the use of proper instrumentation.

6. Machine set-up time is reduced and material is conserved, since fewer test welds are required before

starting a production run.

Approximately 512 hardware-to-sheet and plate thickness combinations were welded using three force settings, twelve current settings and five weld time values.

Thirty-five hardware types in 74 item sizes were welded, these being the hardware items most commonly used throughout the company divisions.

Acknowledgment

The cooperation of the Ohio Nut & Bolt Co. in furnishing samples was sincerely appreciated.

Table 11—Schedule for T-Bolts, Sleeves and Pins

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk.(In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Ckt. Current Turns Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
T-Head Bolt	3/8-16	.062	No.2	1500	10	22,000	25,000	20	1700
	3/8-16	.078		1500	10	22,000	25,000	20	1700
	3/8-16	.094	Hole Size	1500	15	22,000	25,000	20	2000
	3/8-16	.125		1500	15	22,000	25,000	30	2400
	3/8-16	.156		1500	20	22,000	25,000	30	2500
	3/8-16	.188		1500	20	22,000	25,000	30	2500
	3/8-16	.250	No.2	1500	25	22,000	25,000	30	3000
T-Head Flange Welding Sleeve	5/16-18	.062		1500	10	22,000	25,000	20	1700
	5/16-18	.078	No.2	1500	10	22,000	25,000	20	1700
	5/16-18	.094	No.2 Hole Size	1500	15	22,000	25,000	20	2000
	5/16-18	.125		1500	15	22,000	25,000	30	2400
	5/16-18	.156		1500	20	22,000	25,000	30	2500
	5/16-18	.188		1500	20	22,000	25,000	30	2500
	5/16-18	.250	No.2	1500	25	22,000	25,000	30	3000
Weld Pin	3/8 In.	.062		1500	10	23,000	27,000	20	1700
	3/8 In.	.078	No.2	1500	10	23,000	27,000	20	1700
	3/8 In.	.094	No.2 Hole Size	1500	15	23,000	27,000	20	2000
	3/8 In.	.125		1500	15	23,000	27,000	30	2400
	3/8 In.	.156		1500	20	23,000	27,000	30	2500
	3/8 In.	.188		1500	20	23,000	27,000	30	3000
	3/8 In.	.250	No.2	1500	20	23,000	27,000	30	3000

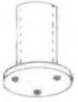
Table 12—Schedule for Flanged-Type Weld Nuts

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk.(In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Ckt. Current Turns Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Flanged Weld Nut	5/16-18	.062	No.2	1500	10	23,000	27,000	20	1700
	5/16-18	.078		1500	10	23,000	27,000	20	1700
	5/16-18	.094	Hole Size	1500	15	23,000	27,000	30	2400
	5/16-18	.125		1500	15	23,000	27,000	30	2400
	5/16-18	.156		1500	20	23,000	27,000	30	2500
	5/16-18	.188		1500	20	23,000	27,000	30	2500
	5/16-18	.250	No.2	1500	25	23,000	27,000	30	3000
	[illegible]	.062	No.2	1500	10	23,000	27,000	20	1700
	5/16-18	.078		1500	10	23,000	27,000	20	1700
	5/16-18	.094	No.2 Hole Size	1500	15	23,000	27,000	30	2400
	5/16-18	.125		1500	15	23,000	27,000	30	2400
	5/16-18	.156		1500	20	23,000	27,000	30	2500
	5/16-18	.188		1500	20	23,000	27,000	30	2500
Flanged Round Flange Weld Nut	5/16-18	.250	No.2	1500	25	23,000	27,000	30	3000
	[illegible]	.062	No.2	1500	10	23,000	27,000	20	1700
	5/16-18	.078		1500	10	23,000	27,000	20	1700
	5/16-18	.094	No.2 Hole Size	1500	15	23,000	27,000	30	2400
	5/16-18	.125		1500	15	23,000	27,000	30	2400
	5/16-18	.156		1500	20	23,000	27,000	30	2500
	5/16-18	.188		1500	20	23,000	27,000	30	2500
	5/16-18	.250	No.2	1500	25	23,000	27,000	30	3000
	.190-32	.062	No.2	1500	10	23,000	27,000	20	1700
	.190-32	.078		1500	10	23,000	27,000	20	1700
	.190-32	.094	No.2 Hole Size	1500	15	23,000	27,000	30	2400
	.190-32	.125		1500	15	23,000	27,000	30	2400
	.190-32	.156		1500	20	23,000	27,000	30	2500
	.190-32	.188		1500	20	23,000	27,000	30	2500
	.190-32	.250	No.3	1500	25	23,000	27,000	30	3000

Table 13—Schedule for Special Type Pins

Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk.(In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Ckt. Current Turns Copper-Amps Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Starter	7/16-14	.062	No.2	2500	10	24,000	28,000	20	1700
	7/16-14	.078		2500	10	24,000	28,000	20	1700
	7/16-14	.094	No.2 Hole Size	2500	15	24,000	28,000	30	2400
	7/16-14	.125		2500	15	24,000	28,000	30	2400
	7/16-14	.156		2500	20	24,000	28,000	30	2500
	7/16-14	.188		2500	20	24,000	28,000	30	2500
	7/16-14	.250	No.2	2500	25	24,000	28,000	30	3000
Testing Sleeve	.190-32	.062	No.2	1500	10	23,000	27,000	20	1700
	.190-32	.078		1500	10	23,000	27,000	20	1700
	.190-32	.094	No.2 Hole Size	1500	15	23,000	27,000	30	2400
	.190-32	.125		1500	15	23,000	27,000	30	2400
	.190-32	.156		1500	20	23,000	27,000	30	2500
	.190-32	.188		1500	20	23,000	27,000	30	2500
	.190-32	.250	No.2	1500	25	23,000	27,000	30	3000
Weld Pin with Flat Shoulder	3/8-24	.062	No.2	1500	10	23,000	27,000	20	1700
	3/8-24	.125		1500	15	23,000	27,000	30	2400
	3/8-24	.156	No.2 Hole Size	1500	20	23,000	27,000	30	2500
	3/8-24	.188		1500	20	23,000	27,000	30	2500
	3/8-24	.250	No.2	1500	25	23,000	27,000	30	3000

Table 14—Schedule for Weld Bolts

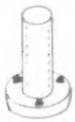


Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (IN.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper—Amps. Note 7	Hold Time Cycles Note 8	Weld Tensile Strength—Lbs. Note 9
Weld Bolt	5/16-18	.078	No.2	1500	10	20,000	23,000	20	2000
	5/16-18	.094	"G"	1500	15	20,000	23,000	20	2400
	5/16-18	.125	Hole	1500	15	20,000	23,000	30	2600
	5/16-18	.156	Size	1500	20	20,000	23,000	30	2600
	5/16-18	.188		1500	20	20,000	23,000	30	2800
	5/16-18	.250	No.2	1500	25	20,000	23,000	30	3000
	3/8-16	.078	No.2	1500	10	20,000	23,000	20	2200
	3/8-16	.094	"H"	1500	15	20,000	23,000	20	2500
	3/8-16	.125	Hole	1500	15	20,000	23,000	20	2600
	3/8-16	.156	Size	1500	20	20,000	23,000	30	2800
	3/8-16	.188		1500	20	20,000	23,000	30	2800
	3/8-16	.250	No.2	1500	25	20,000	23,000	30	3000
	1/2-13	.094	No.2	1500	15	22,000	26,000	20	2600
	1/2-13	.125	"K"	1500	15	22,000	26,000	30	3000
	1/2-13	.156	Hole	1500	20	22,000	26,000	30	3000
	1/2-13	.188	Size	1500	20	22,000	26,000	30	3500
	1/2-13	.250	No.2	1500	25	22,000	26,000	30	3500

Table 15—Schedule for Weld Pins

Name & Sketch of Pin Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper - Amps. Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Pin	1/4 In.	.032	No. 2	[illegible]	[illegible]	[illegible]	18,000	[illegible]	700
	1/4 In.	.064	"A"	[illegible]	[illegible]	[illegible]	18,000	[illegible]	900
	1/4 In.	.078	Hole	[illegible]	[illegible]	[illegible]	18,000	[illegible]	1200
	1/4 In.	.094	Size	[illegible]	[illegible]	[illegible]	18,000	[illegible]	1200
	1/4 In.	.125		[illegible]	[illegible]	[illegible]	18,000	[illegible]	1400
	1/4 In.	.156		[illegible]	[illegible]	[illegible]	18,000	[illegible]	1400
	1/4 In.	.188	No. 2	[illegible]	[illegible]	[illegible]	18,000	[illegible]	1500
	1/4 In.	.250		[illegible]	[illegible]	[illegible]	18,000	30	1800
	.312 In.	.078	No. 2	[illegible]	10	20,000	23,000	20	2200
	[illegible]	.094	"H"	[illegible]	15	20,000	23,000	20	2500
	[illegible]	.125	Hole	[illegible]	15	20,000	23,000	20	2500
	[illegible]	.156	Size	[illegible]	20	20,000	23,000	30	2800
	[illegible]	.188		[illegible]	20	20,000	23,000	30	2800
	3/8 In.	.250	No. 2	[illegible]	25	20,000	23,000	30	3000
	1/2 In.	.094	No. 2	[illegible]	[illegible]	[illegible]	26,000	[illegible]	[illegible]
	1/2 In.	.125	"K"	[illegible]	[illegible]	[illegible]	26,000	[illegible]	3000
	1/2 In.	.156	Hole	[illegible]	[illegible]	[illegible]	26,000	[illegible]	[illegible]
	1/2 In.	.188	Size	[illegible]	[illegible]	[illegible]	26,000	[illegible]	[illegible]
	1/2 In.	.250	No.2	[illegible]	[illegible]	[illegible]	26,000	[illegible]	[illegible]

Table 16—Schedule for Weld Screws



Name & Sketch of Part Note 1	Size or Dia. & Thread Note 2	Sheet or Plate Thk. (In.) Note 3	Electrode Comb. Dia. & Shape Note 4	Welding Force Lbs. Note 5	Weld Time Cycles	Welding Current Amps. Note 6	Short Cir. Current Thru Copper - Amps. Note 7	Hold Time Cycles Note 8	Weld Tensile Strength Lbs. Note 9
Weld Screw	.138-32	.032		1000	5	14,500	17,000	15	[illegible]
	.138-32	.064	No.1	1000	10	14,500	17,000	20	[illegible]
	.138-32	.078	"A"	1000	10	14,500	17,000	20	700
	.138-32	.094	Hole	1000	15	14,500	17,000	20	800
	.138-32	.125	Size	1000	15	14,500	17,000	30	[illegible]
	.138-32	.156		1000	20	14,500	17,000	30	[illegible]
	.138-32	.188	No. 1	1000	20	14,500	17,000	30	[illegible]
	.138-32	.250		1000	25	14,500	17,000	30	[illegible]
	.190-32	.032	No.2	1500	5	16,000	19,000	15	[illegible]
	.190-32	.064		1500	10	16,000	19,000	20	[illegible]
	.190-32	.078	[illegible]	1500	10	16,000	19,000	20	[illegible]
	.190-32	.094	Hole	1500	15	16,000	19,000	20	800
	.190-32	.125	Size	1500	15	16,000	19,000	30	900
	.190-32	.156		1500	20	16,000	19,000	30	1000
	.190-32	.188	No.2	1500	20	16,000	19,000	30	1100
	.190-32	.250		1500	25	16,000	19,000	30	1200
	1/4-20	.032		1500	5	16,000	19,000	15	[illegible]
	1/4-20	.064	No.2	1500	10	16,000	19,000	20	[illegible]
	1/4-20	.078	[illegible]	1500	10	16,000	19,000	20	900
	1/4-20	.094	Hole	1500	15	16,000	19,000	20	1000
	1/4-20	.125	Size	1500	15	16,000	19,000	30	1000
	1/4-20	.156		1500	20	16,000	19,000	30	1100
	1/4-20	.188	No.2	1500	20	16,000	19,000	30	1100
	1/4-20	.250		1500	25	16,000	19,000	30	1200

Table 17—Schedule for Weld Pins

Table 18—Schedule for Square and Rectangular Welds Nuts

Table 19—Schedule for Weld Pins and Brackets

Table 20—Schedule for Standard Pilot Nuts

Table 21—Schedule for Standard Pilot Nuts

Table 22 Specimen Machine Data Chart Rocker Arm 250-kva Spot Welder

Welding current, amp	*Meter reading for welding current*	*Short-circuit current through copper, amp*	*Meter reading through copper*	*Meter range switch*	*Heat control dial (approx.)*	*Tap setting*	*Welding force, lb*	*Gage pressure, lb*
7,000	230	8,200	270	1	35½	Lo-1	250	5
8,400	280	9,900	330	1	40½	Lo-1	400	8
9,200	310	10,800	360	1	45½	Lo-1	600	12
11,400	380	13,400	450	1	50½	Lo-1	800	16
14,600	490	17,200	575	2	35½	Hi-1	1300	25
19,200	330	22,600	380	3	40½	Hi-1	2200	42
22,200	370	26,100	435	3	47½	Hi-1	2700	52
28,000	470	33,000	550	3	55½	Hi-1	3700	70

CUPRO-NICKEL WELDED WITH ALUMINUM BRONZE

Results of test program indicated that AWS-ASTM classification ECuAl-A2 electrodes can be successfully used with the inert-gas consumable-electrode process to eliminate weld-deposit cracking

BY VINCENT ABARAVICH

With the introduction of 90-10 cupro-nickel within recent years to replace the old 70-30 alloy as the result of a nickel shortage, difficulties have consistently occurred in the fabrication of this alloy due, primarily, to its hot-short characteristics.

In an effort to develop a more satisfactory method of joining 90-10 cupro-nickel, a series of tests has been conducted by Ampco Metal, Inc., indicating that AWS-ASTM classification ECuAl-A2 electrodes can be successfully used with the inert-gas consumable-electrode process to eliminate weld-deposit cracking entirely.

Copper-Nickel Alloys

Although the cupro-nickels are classified as alloys containing between 5% and 45% nickel with the balance essentially copper, the 10% and 30% nickel types are those most commonly used in sheet and plate form for welded fabrications.

The 30% nickel type, previously used commercially, has a nominal composition of 70% copper and 30% nickel and is generally referred to as 70-30 cupro-nickel or copper-nickel 30%. The new 10% nickel alloy has a nominal composition of 88.5% copper, 10% nickel and 1.5% iron and is generally known as 90-10 cupro-nickel or copper-nickel 10%. Other metal additions to these two general types of copper-nickel alloys are allowable under the ASTM-B-171-55 and MIL-C-15726A (Ships) specifications shown in Table 1.

Due to the relatively high-nickel content of these alloys, they do exhibit good resistance to erosion and corrosion. They are quite satisfactorily used to resist the corrosive and erosive attacks of high-velocity sea water with the resistance usually increasing in direct proportion to the increasing nickel content of the alloy. Also, the alloys are adaptable to cold working which makes them suitable for the fabrication of condenser shells and tubes, evaporators, heat exchangers, fresh and salt water stills and other related chemical processing equipment.

Present Fabricating Methods

The 70-30 copper-nickel alloy has been used successfully for fabrications in the past but the short supply of nickel in the metal market has resulted in the substitution of the 90-10 alloy for many applications in more recent years. Although not as good as the old 70-30 composition for some applications, the 90-10 alloy does seem to compare favorably under certain salt-water operating conditions.

Prior to the introduction of the new 90-10 alloy, the metal-arc process with covered ECuNi electrodes was used almost exclusively for the fabrication of cupro-nickel. However, it has been found that the inert-gas welding processes are much more economical in producing joints of much higher quality with less repair.

Although some difficulties were always encountered in the welding of the 70-30 type due to the hot-short characteristics inherent in the alloy, this condition became more pronounced with the introduction of the 90-10 type. Because of its higher thermal conductivity (almost double that of the 70-30 alloy), higher current

Table 1—Cupro-Nickel Specifications

	—ASTM-B-171-55—		—MIL-C-15726A (Ships)—	
Element	*90-10*	*70-30*	*90-10*	*70-30*
Copper	85.5 min	65.0 min	Bal	65.0 min
Nickel	11.0	29.0-33.0	9.0-11.0	29.0-32.0
Iron	0.50-2.0	0.7 max	1.00-1.75	0.40-0.70
Manganese	1.0 max	1.0 max	0.75 max	1.0 max
Zinc	1.0 max	1.0 max	1.0 max	1.0 max
Lead	0.05 max	0.05 max	0.05 max	0.05 max
Minimum tensile strength, psi	40,000	50,000	38,000	45,000

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densities are necessary in order to flow the weld metal effectively into the side walls. The higher heat necessary in welding this hot-short alloy results in excessive deposit cracking when 90-10 electrodes or filler rods are used.

In an effort to reduce cracking, special techniques were developed using ECuNi (70-30) electrodes and filler rods with the inert-gas processes in order to join the alloy with any degree of satisfaction.

The use of the inert-gas consumable-electrode process does assure weld deposits of good quality with regard to soundness, and welding can be performed at the highest rate of speed attainable reducing the tendency to hot-shortness and, therefore, deposit cracking if the joint is not inadvertently overheated or not too highly stressed.

Either argon or helium gas can be used. Reverse (electrode positive) polarity, direct current is recommended. To obtain adequate gas coverage, the rate of flow of the gas should be at least 30 cfh.

String beads in moderately thin layers deposited at high current densities and at a fast rate of travel are necessary to minimize cracking with ECuNi spooled wire. Interpass temperature should not exceed 150°F in multipass welding.

Generally, the inert-gas tungsten-arc process is used for joining light-gage cupro-nickel sheet using a filler rod of the AWS-ASTM classification RCuNi. No flux is required because of the excellent shielding of the inert-gas cover. Either argon or helium gas can be used with straight (electrode negative) polarity, direct current or alternating current.

Welding is usually done in the flat position, although skilled operators can apply the deposit in the vertical and overhead positions.

Many applications for cupro-nickel require that it be joined to steel. Monel electrodes and filler rods have been recommended for this type of welding; however, deposit cracking is encountered frequently.

Test Program

Due to the cracking troubles encountered in the use of ECuNi and RCuNi electrodes and filler rods in the joining of 90-10 cupro-nickel, plus the continued shortage of nickel resulting in long delays and uncertain procurement, several fabricators of cupro-nickel, looking for a satisfactory substitute, found that the ECuAl-A2 and RCuAl-A2 electrodes and filler rods could be used most successfully to join cupro-nickel to itself as well as to steel with the inert-gas processes. The aluminum-bronze deposits had much less tendency to be hot-short than either the 70-30 or 90-10 cupro-nickel and Monel deposits.

In fact, some large fabricators, when cracking occurred using specified and conventional methods of joining with ECuNi electrodes, successfully repaired these welds by chipping out the cracked areas and re-welding with ECuAl-A2 electrodes and RCuAl-A2 filler rods.

These findings led to requests from fabricators to conduct confirming tests with regard to weldability to verify the results obtained in the shop.

Table 2—Typical Chemical Compositions

	90-10 Plate	ECuAl-A2	Weld deposit
Copper, %	87.53	89.34	88.97
Aluminum, %		9.85	7.84
Nickel, %	10.40	0.06	2.18
Iron, %	1.58	0.75	1.00
Manganese, %	0.07	0.01	0.01
Others, %	0.42	0.01	0.01

Accordingly, a complete test program was initiated using cupro-nickel plate trimmings supplied by a fabricator of the alloy. Composition of the plate conformed to MIL-C-15726A (Ships) 90-10 alloy (see Table 2).

The welding was done in the downhand position, with the work fully restrained to induce stresses. AWS-ASTM ECuAl-A2 spooled wire (Table 2) and the inert-gas consumable-electrode process were used with standard methods and techniques. Shop personnel familiar with a wide variety of joining operations, but unfamiliar with the welding of cupro-nickel or cupro-nickel to steel, were used to weld the test plates.

Equipment

All of the equipment employed was of commercial design using standard and widely used types of accessories with no special precautions, adjustments or other modifications.

The power source was a three phase, direct current rectifier-type welding machine with a 230/460 volt, 62/31 amp primary and 35 volt, 500 amp, secondary. A voltmeter and ammeter were used to indicate arc voltage and welding current.

Temperature readings were made with the aid of a standard contact pyrometer. Argon and helium were used as the shielding gases with standard regulators and flowmeters calibrated in cfh. The argon-helium gas mixture was obtained by means of a Y-tube.

Welding

Several sets of test plates were prepared using $^3/_8$- and $^3/_4$-in. thick 90-10 cupro-nickel with a 70 deg over-all single V-groove which is considered a standard groove design for copper-alloy welding. A root spacing of $^1/_{16}$ in. was used to secure adequate penetration into a heavy-grooved copper backing plate. All test plates were securely clamped down to obtain maximum stresses in the joint in an effort to induce cracking.

Conventional inert-gas consumable-electrode equipment was used with reverse polarity, direct current under the condition shown in Table 3 with a 50-50 mixture of helium and argon. Argon provides excellent arc characteristics with low spatter, producing a clean-appearing deposit, while helium improves penetration and deposit density.

The $^3/_8$-in. plates required 3 layers and the $^3/_4$-in. plates required 6 layers. Interpass temperature was maintained at 300° F and all welds were back-chipped

Table 3—Welding Conditions

Plate thickness, in.	*Wire diameter, in.*	*Number of layers*	*Interpass temperature*	*Volts*	*Amperes*	*Gas flow*
3/8	5/32	1 & 2 string 3 weave	300° F	38	350	30 cfh Argon & 30 cfh Helium
3/4	5/32	1, 2 & 3 string 4, 5 & 6 weave	300° F	38	350	30 cfh Argon & 30 cfh Helium

to clean metal with one layer applied to the back side. The test plates were allowed to air cool normally to room temperature before removal of the clamps. No cracks were in evidence during or after welding.

All finished test plates were X-rayed and found to be acceptable by ASME Boiler Code Standards. A typical example is the X-ograph of one of the weld joints shown in Fig. 1.

The 3/8-in. thick test plates were machined to secure two reduced-section tensile specimens, two face-bend specimens, two root-bend specimens and one metallographic section for macroscopic examination from each. The 3/4-in. thick test plates were sectioned and machined into two 0.505-in. all-weld metal specimens and the slugs from the ends used for hardness determination and for macroscopic studies.

Test Results

All test specimens were standard and all physical tests made in accordance with AWS, ASTM and ASME requirements. The results are shown in Tables 4 and 5.

It should be observed that all joint tensile specimens failed in the 90-10 cupro-nickel base plates or the fusion zone, Fig. 2, and that all ultimate tensile strengths do compare favorably with the actual ultimate tensile strength of the plate which was tested at the same time under identical conditions. Bend-test results were also comparable.

The mechanical properties obtained from the 0.505-in. all-weld metal specimens (as-welded), Fig. 3, were considerably higher than those exhibited by the flat specimens since the ECuAl-A2 electrode deposit and the resultant alloy produced in the joint through admixture are inherently higher in strength than the base metal, Table 5.

Table 4—Summary of Flat Joint Weld Test Results (As-Welded)

	Ultimate tensile strength, psi	*Face bend*	*Root bend*
90-10 Cupro-nickel plate	47,500	180°	180°
90-10 Cupro-nickel plate	48,100	180°	180°
Welded joint	47,500	180°	180°
Welded joint	47,600	180°	180°
Welded joint	47,000	180°	180°
Welded joint	47,800	180°	180°

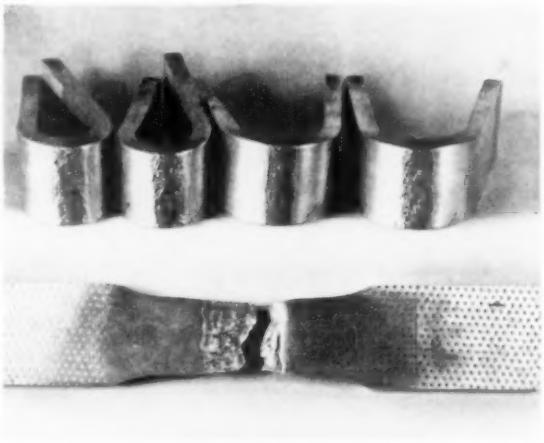


Fig. 2 Typical joint tensile and bend-test specimens indicating good strength and ductility, as-welded

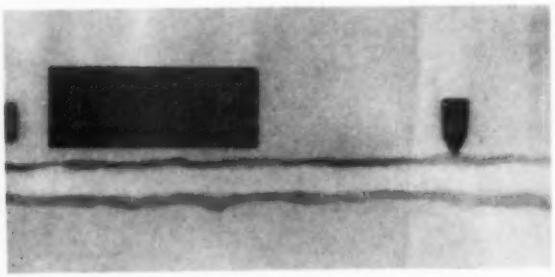


Fig. 1 X-ograph of ECuAl-A2 weld in 90–10 cupro-nickel plate

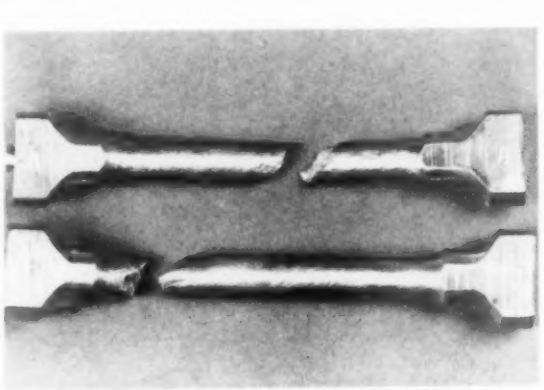


Fig. 3 Representative 0.505-in. all-weld metal tensile-test specimens, as-welded

Table 5—Summary of 0.505-in. All-Weld Metal Test Results (as-Welded)

Ultimate tensile strength, psi	*Yield strength 0.2% ex, psi*	*Elongation % in 2 in.*	*Reduction of area, %*	*Brinell hardness*
56,600	26,700	32.0	34.6	131
48,700	26,000	34.0	26.0	126
49,200	26,100	33.5	27.5	127
51,500	26,500	32.5	30.2	129
50,600	26,200	33.0	27.8	128
51,200	26,400	32.5	29.2	130

Fig. 4 Hardness survey across the joint cupro-nickel welded to cupro-nickel with ECuAl-2 electrodes

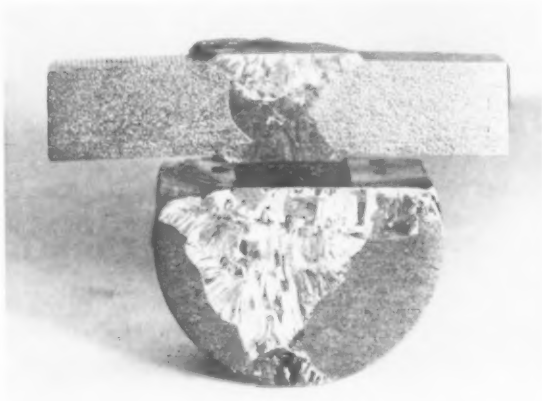


Fig. 5 Metallographic sections from $^3/_8$- and $^1/_4$-in. 90–10 cupro-nickel test plates showing crystalline structure. X $1^1/_2$. (Reduced by 40% upon reproduction)

A complete hardness survey was made using metallographic coupons from both types of joints. Two sets of readings were taken, one near the top of the joint and the other set near the bottom or root of the joint in order to determine changes produced by the heat of the welding operation and by the alloying effect of nickel and iron in the weld deposits. The results are shown in Fig. 4.

Note that the heat-affected zone of the 90-10 cupro-nickel plate shows a softening and then a gradual hardening as the survey proceeds away from the weld. This condition, undoubtedly, is indicative of the reason for the failure in tension in the heat-affected zone.

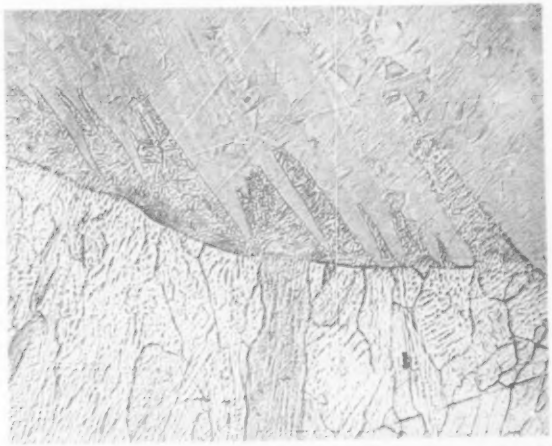


Fig. 6 Photomicrograph of fusion line between 90–10 cupro-nickel base metal (*top*) and ECuAl-A2 deposit (*bottom*). X 80. (Reduced by $^1/_4$ upon reproduction)

The metallographic sections taken from each test plate were examined, after etching with dilute nitric acid, and found to be free from cracks and macroporosity. Figure 5 shows the etched macrosection of the ECuAl-A2 deposit in the 90-10 cupro-nickel plates at $\times$ $1^1/_2$ magnification.

Figure 6 shows the fusion line between the 90-10 cupro-nickel plate and the aluminum-bronze weld deposit at $\times$ 80 magnification using ferric chloride as the etchant. Weld deposit penetration can be noted along the fusion line which indicates good bonding. The aluminum-bronze deposit shows a coring effect due to a nickel pickup from the base plate.

Steel to Cupro-Nickel

At the suggestion of a large shipbuilding concern, which welds cupro-nickel to steel quite extensively using Monel electrodes and filler rods, preliminary tests were conducted welding 90-10 cupro-nickel to SAE 1020 steel, with the inert-gas consumable-electrode process using $^1/_{16}$-in. diam ECuAl-A2 spooled wire.

The same groove preparation and procedures were followed as described for welding 90-10 cupro-nickel to 90-10 cupro-nickel using $^3/_4$-in. plate in order to secure 0.505-in. tensile test specimens across the joint,

Fig. 7 Test plate showing ECuAl-A2 weld in 90–10 cupro-nickel and SAE 1020 steel

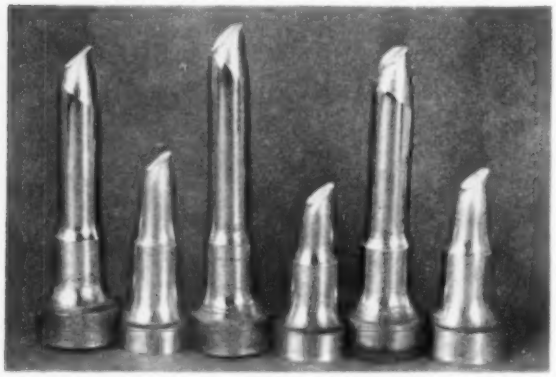


Fig. 8 0.505-in. tensile specimens taken across the 90–10 cupro-nickel to SAE 1020 steel joint. Breaks occurred in cupro-nickel

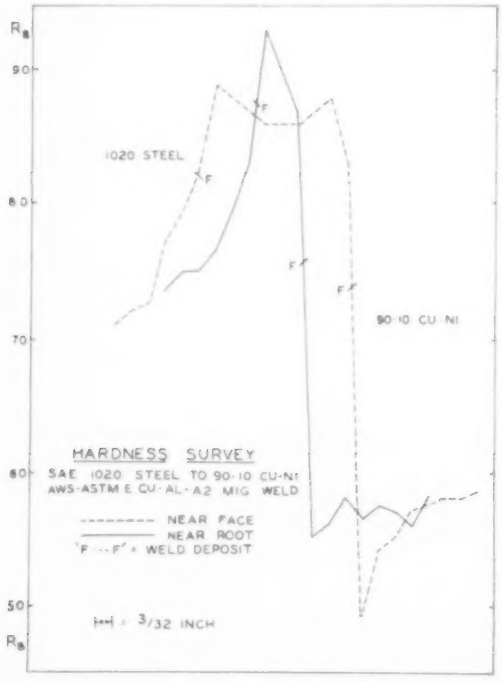


Fig. 9 Hardness survey across the joint SAE 1020 steel to 90–10 cupro-nickel with ECuAl-A2 deposit

Table 6—Summary of 0.505-in. Steel to Cupro-Nickel Test Results (as-welded across the weld)

Ultimate tensile strength, psi	*Yield strength 5% E, psi*	*Elongation, % in 2 in.*	*Reduction of area, %*	*Remarks*
49,500	35,900	19.0	56.7	Broke in Cu-Ni
47,000	35,700	17.5	56.2	Broke in Cu-Ni
49,500	35,900	20.0	50.3	Broke in Cu-Ni
48,000	35,800	18.5	52.7	Broke in Cu-Ni

Weld appearance and X-ray quality were comparable to the 90-10 cupro-nickel joints as shown in Fig. 7.

The steel to 90-10 cupro-nickel test plates were sectioned and machined to obtain standard 0.505-in. tensile test specimens across the joint. Typical test specimens are shown in Fig. 8. All failures occurred in the 90-10 cupro-nickel plate some distance from the weld metal since it is the weaker member. Therefore, the test results shown in Table 6 are indicative of plate values only.

A hardness survey was conducted across the joint, Fig. 9. Welding definitely has a hardening effect upon the heat-affected zone at the steel side of the joint indicating a marked increase in strength contrasted to a softening effect in the heat-affected zone at the 90-10 cupro-nickel side of the joint. The ECuAl-A2 weld deposit is, of course, considerably stronger than either the SAE 1020 steel or the 90-10 cupro-nickel in the as-rolled condition.

Conclusion

The results of this investigation indicate that aluminum-bronze electrodes of the AWS-ASTM classification ECuAl-A2, when used with the inert-gas consumable-electrode process, can be successfully used to join 90-10 cupro-nickel and 90-10 cupro-nickel to SAE 1020 steel for fabrication purposes.

No weld failures were encountered during the course of this investigation, such as cracking or excessive porosity using standard, accepted methods and techniques by welding operators unfamiliar with the welding of 90-10 cupro-nickel although attempts were made to induce failure.

Although no attempt was made in these tests to establish comparative corrosion- and erosion-resistant qualities, by the very nature of the two alloys and their recommended uses, it can be assumed that 90-10 cupro-nickel and the ECuAl-A2 deposit are suitable for most applications. Additional field and laboratory tests are being conducted to determine definitely the resistance of such joints in various corrosive media.

Acknowledgment

The author desires to acknowledge help given by J. F. Klement, B. A. Kalvelage, R. Maersch, H. H. Hose, W. E. Claflin, W. Gruss and F. E. Garriott in the preparation of this paper.

Power and flashing speed—but the efficiency of this high-speed twin-screw crewboat will be drastically reduced as its propellers become damaged

AN OLD WELDING PROCESS CHEATS THE SEA

Paper discusses the application of oxyacetylene welding in the reconditioning and rebuilding of manganese-bronze marine propellers

BY L. L. WALKER, JR.

ABSTRACT. This paper discusses the employment of oxyacetylene fusion welding in the reconditioning and rebuilding of manganese-bronze marine propellers.

This rebuilding is accomplished solely with bronze welding rods and a dry flux. All of the welding, even to the restoration of missing blade ends, is accomplished without any type of backing material.

This paper discusses the evolution of the process and the reasons for the selection of the welding rods used. It also discusses a technique by which the individual welding rods are made to describe the blade shape where the blade has been worn away and are then fused together by the oxyacetylene flame to form literally the new blade section. The properties of the welded areas and their resistance to further abrasion and corrosion are discussed.

The process described has been under development for more than twenty-five years, and the present scope of its application by the author's company is evidenced by an annual use of between seven and eight tons of bronze welding rods.

L. L. Walker, Jr. is Vice-President and Manager of the L. L. Walker Co., Houston, Texas.

Alternate paper for 1958 AWS National Spring Meeting to be held in St. Louis, Mo., April 14–18.

Introduction

In view of the technical progress in the welding industry and in view of the industry's giant strides toward semi-automatic operation and automation, it may come as a surprise to some people to know that oxyacetylene

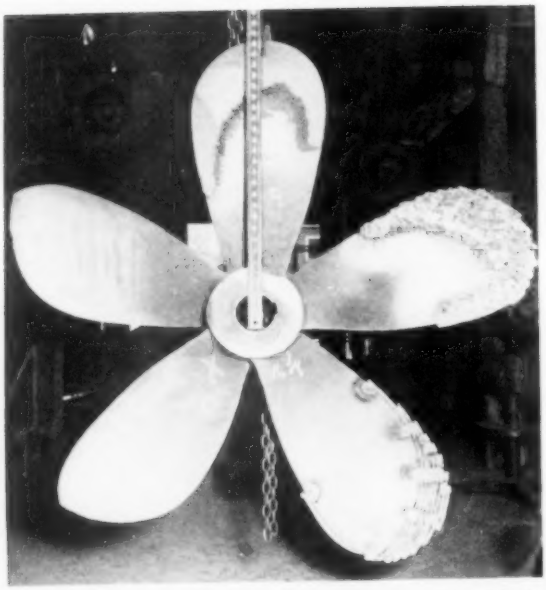


Fig. 1 Fifty-two inch diameter propeller. Two blades show extent of wear. Other three blades have been specially prepared to illustrate steps in rebuilding operation

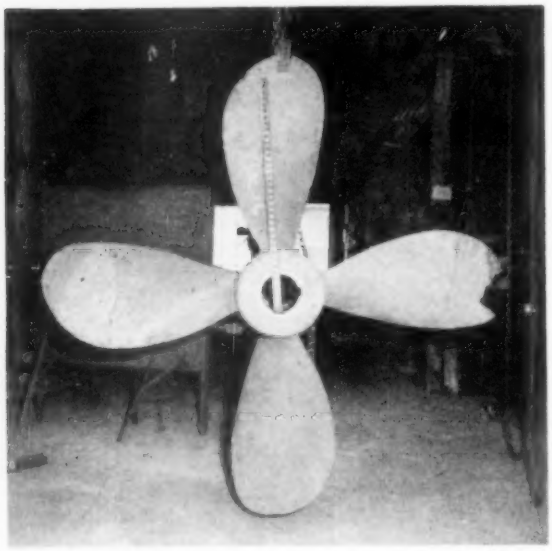


Fig. 2 A 72-in. diam propeller with badly wasted blade ends. While not clearly visible here, the ends are so thin that one has torn away. At inboard end of tear the blade thickness reduction is 40%

welding in the traditional manner still makes a major contribution to a minor segment of the industry.

This old process has been found to be the most satisfactory one in the rebuilding of bronze marine propellers. The sea constantly makes its demands but, in the case of propellers, what it takes away can be restored quickly, economically and satisfactorily by oxyacetylene welding. Truly, an old welding process cheats the sea.

Marine propellers of all sizes are generally cast from manganese bronze. In recent years there has been a trend toward the stainless steels and the nickel-aluminum bronzes for propellers having certain special service requirements, but by far the greater number of propellers in service are of manganese bronze. As is well known, bronzes of this type can best be welded by the oxyacetylene process. This paper discusses the employment of the oxyacetylene welding process in the reconditioning and rebuilding of manganese-bronze propellers.

Marine propellers are designed in two, three, four and even five blade types. By far the great majority of all propellers of all sizes have either three or four blades. The propeller is generally a solid casting with its blades integral with the central hub, or boss, which is itself bored to fit the propeller shaft. The blades are positioned on the hub at a predetermined angle so as to produce a desired geometrical-pitch. There are in use both adjustable and controllable-pitch propellers, but these are not generally seen. These propeller castings range in weight from a few pounds for an outboard motor to upward of 80,000 lb for the newest super-tankers. The process described in this paper, however, is generally applicable to the repair of propellers weighing up to about 12,000 lb.

The average propeller bronze is an alloy of about 56 to 58% copper, 38 to 39% zinc, about 1% iron and something less than one percent of manganese. The tensile strength ranges up to 78,000 lb with elongation averaging 25 to 28%. Hardness of a new propeller usually ranges from 121 to 123 Brinell. As may be supposed, various manufacturers offer their own alloys with slightly varying characteristics, but the foregoing is fairly representative.

Kinds of Propeller Damage

In general, bronze propellers have good impact characteristics, but even so the most common type of damage is that of blade bending. These bent propellers may be straightened, hot or cold, as the conditions may dictate and no welding at all may be necessary.

However, many inshore waters—particularly those of the Gulf Coast—are quite shallow, and vessels required to work in these waters suffer rapid and sometimes drastic propeller wear due to abrasion. Shallow water work also makes for much blade edge breakage and tearing. Where wear is due to abrasion by constant contact with the bottom such action tends to reduce the propeller diameter without materially affecting the blade thickness.

On the other hand, vessels operating for protracted periods in deep water may suffer severe wasting away of the blade thickness without any significant reduction in diameter.

Thus it will be seen that propeller repairs involving oxyacetylene welding are of three general types:

1. The restoration of blade area worn away by work in shallow water. The 52-in. diam propeller in Fig. 1 typifies the nature of this wear.

2. The restoration of blade thickness wasted away by

work in deep water. The 72-in. diam propeller in Fig. 2 has blade ends wasted so thin that one has torn away under relatively slight impact.

3. The welding of breaks and tears in the blades. Figure 3 shows an 80-in. diameter propeller with extensive damage to all four blades.

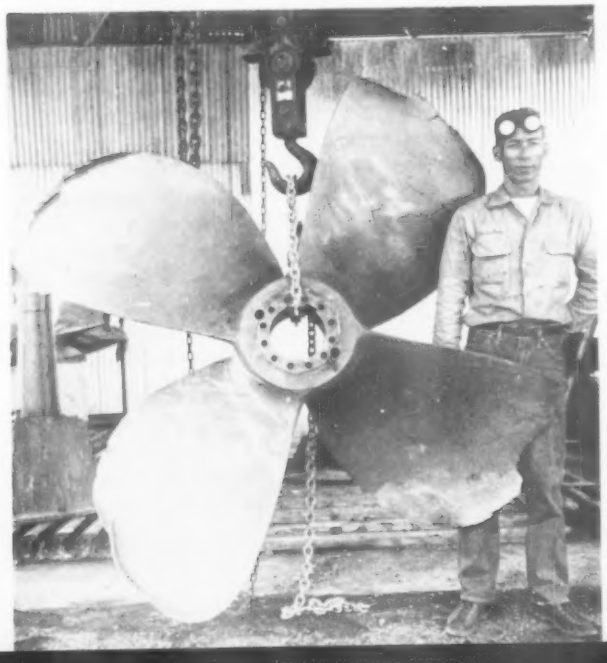
Preparation of Work

Cleaning of the area to be welded is no problem in most cases. The only exception is where corrosion is involved. Although manganese bronze has a high level of corrosion resistivity, such damage nevertheless occurs for reasons that are not fully and clearly understood.

Corrosion in bronze propellers is frequently of the laminar dezincification type with successive discernible layers of corrosion product marking the extent of the penetration. The laminar deposit makes possible a rather uniform removal of the corrosion product to expose uncorroded metal to which the weld metal may be fused. This removal must be done prior to welding because fusion would not otherwise be possible due to the chemical differences between the corrosion product and the weld metal. Of course, if the corrosion penetration is so deep that no sound metal can be exposed, then no rebuilding is possible and the propeller must be scrapped.

Since the operation of restoring worn or torn areas is dependent upon the welder's being able to define the original or desired shape, it is first necessary to lay out the blades so that the shape may be defined by one or more settings of dividers in the hand of the welder as his work progresses. Bent blades and torn or ragged blade edges must first be faired out before the blade geometry, or layout, can be accomplished. When all this has been done, the propeller is placed on a specially constructed positioner, and the welder is ready to begin.

Fig 3. A badly damaged 80-in. diam propeller weighing 2000 lb. Note extensive damage caused by striking submerged object



Choice of Welding Rod

The welder does his work with welding rods of AWS-ASTM Classification RCuZn-C in diameters of from $\frac{3}{16}$ to $\frac{1}{2}$ in. The reasons for the selection of this particular type of rod are simple:

1. The chemical analysis of RCuZn-C welding rod is markedly similar to that of the average propeller bronze.

2. The RCuZn-C rod has good mechanical properties quite similar to those of the base metal, thus posing no problems in the grinding and working of the welded areas.

3. Classification RCuZn-C rod displays highly desirable qualities of corrosion resistance. With rare exceptions—and these attributable to some irregularity in the rod manufacturing process—the welded areas are free of iron segregation after exposure to the elements or to salt water.

4. There is, between this welding rod and the average propeller alloy, a good and uniform color match. Whether or not the color match has any other virtue, it is pleasing to the eye and tends to be the visual evidence of finished workmanship.

5. The low-fuming character of the rod is particularly helpful where welding is being done in great quantity and for long periods of time.

Flame and Fluxing

For the normal work, the welder uses a neutral to slightly-oxidizing flame and endeavors to maintain the flow of metal at the lowest possible working temperature.

The nearly-neutral flame is possible in welding uncorroded metal for at least two reasons:

1. The RCuZn-C rod itself contains film-forming elements that retard the vaporization of the zinc.

2. The flux has been chosen because of its ability to combine readily with the oxides of zinc and other metals.

Relieved of the necessity of using an oxidizing flame merely to control oxidation, the welder may proceed with the assurance of a weld that is quite free of oxide inclusions.

Where corrosion products are present and cannot be completely removed in advance of welding, or where there is some substantial variation or imperfection of the propeller alloy, a more oxidizing flame is necessary. Obviously, there is the real possibility of greater oxide inclusions to the detriment of the welded area, but this is a risk that must be accepted in order to salvage the propeller.

Normally, the welding flux is designed to handle only those oxide conditions arising from the welding operation. Under these circumstances, the flux residue is not great in volume and it is readily removable. When, however, an area is encountered in which extensive oxide contamination exists, and this area cannot be adequately precleaned, then it is necessary to use a liberal application of welding flux. This results in a large amount of flux residue. Further, because of the

bad oxide condition, the flux has had to react with this large amount of oxide, thus producing a flux residue which is of a glassy nature. Such flux glass residues are more difficult to remove.

Thus, it can be seen that variations of the flame adjustment and variations in the flux application will, in themselves, accommodate the RCuZn-C welding rod to a wide range of alloy variations and local conditions.

Since it is necessary to vary the flux application, it should be explained that the flux used in this process is combination of two proprietary fluxes of AWS Type No. 4, as defined in the AWS Brazing Manual. The proportions of the mixture may be varied to cope with the varying work conditions and the welder may vary the quantity of flux used at the time of welding.

Evolution of the Process

The process described here has been under development by the writer's company for some thirty years. No claim is made for originating the idea of propeller reconditioning in itself. However, it is certainly true that the writer's company was one of the first to realize the advantages of rebuilding bronze propellers by oxyacetylene welding.

In the beginning, the work was done in a rather laborious manner. When the checking of the blade geometry was completed and the size and shape of the missing area had been determined, a wooden pattern was prepared and the suitable number of castings was made in the foundry. These castings were then joined to the blades by oxyacetylene welding. This was a highly satisfactory process in most respects, but it was time consuming and could not be readily adapted to the emergency needs of the customer.

Later, it was found that missing areas could be restored by the careful shaping and fusion of the welding rods themselves. But it was thought that this could only be done against suitable asbestos backing. The placing of the backing material, however, was also a time consuming operation, and the principal merit of procedure was simply that it freed the foundry of the necessity of casting the replacement sections.

In the course of time, less reliance was placed on the backing, and finally it became apparent that any worn area could be built up by the welding rods and complete fusion secured without any backing and without any appreciable burn-through. So it is that the entire process involves only brass welding rods, a suitable flux and the oxyacetylene torch.

Present Procedure

In the restoration of diameter, the welder positions the propeller blade so that it is substantially flat. Beginning at a convenient point on one blade, he tacks welds on a rod of an appropriate size. He then heats the rod sufficiently to bend it and proceeds around the blade edge to the limit of the required weld area, tacking the rod to the blade at suitable intervals. He then proceeds with the application of successive courses of welding rod of suitable diameters to restore the missing area. When this is completed, he returns to the point of his beginning and proceeds to fuse the first course into the base metal and the successive courses into each other. The penetration is slightly more than one-half of the diameter of the welding rods. When one entire surface of each blade has been welded in this manner, the propeller is turned over and the welder begins again on the same blade and at the same point where he started. This time, however, he is fusing the welding rods and the base metal from the previously unwelded side and is also applying filler metal to bring the blade to the thickness desired.

It is interesting to note that eighteen to twenty courses of $^{3}/_{8}$-or $^{1}/_{2}$-in. diam rod can be applied in this manner and then fused together without any unwelded voids. Figure 4 shows twenty courses.

In cases where there has been no appreciable reduction in diameter but where blade thickness has been wasted away, the procedure differs slightly.

Because the blade edges can become remarkably thin under such wasting, it is necessary to weld a boundary rod around the blade edges. The welding of this rod to such a thin section demands the greatest care so that fusion occurs just short of the point where the thin section of the wasted blade burns through. Once the boundary rod has been secured, however, it gives the welder a firmer base for the work that follows.

The welder proceeds inward from this boundary rod with the application of the weld metal, and this metal is laid on to a depth that will permit restoration of the original section thicknesses. The application of weld metal is done first on one side of the blade and then on the other. It should be pointed out that this is not merely a brazing or braze-welding operation. It is welding in the truest definition.

Special care must be given to cracks as distinguished from tears, because these may often be the evidence of an unstable alloy or of residual stresses due to manufacture or to some previous improper repair.

Cracks in propeller blades usually begin at the blade edge and radiate inward. Occasionally, cracks will be found in the blade roots or in the hub, but they are treated differently and will be covered later in this paper.

In the case of blade edge cracks it is first necessary to define the limits of the crack. If there is not sufficient visual evidence, the area is checked with a dye-penetrant system of inspection. If the cracked sections are sufficiently thin, the crack may be washed out with the torch; otherwise, the area of the crack is ground or chipped from both sides of the blade. This area is carefully brought up to temperature, the welder observing carefully any evidence of further cracking. Weld metal is applied first from one side and then the other until full closure is effected. Figure 5 shows a blade-edge crack in a sixteen thousand pound propeller.

Preheating

It will have been noted that nothing has been said about preheating. By preheating, in our work, we understand it to be a procedure for the separate application of heat for the gradual elevation of the tempera-

ture of the workpiece prior to beginning the weld. In that strict sense, the procedure is used only to a limited degree in the process under discussion.

In the smaller propellers—those up to perhaps six feet or more in diameter—the sections are usually thin enough to permit the welder, with a few passes of his torch, to bring the temperature of the propeller blade adjacent to his work to an acceptable level. In such propellers there is no difficulty in maintaining adequate heat throughout the entire time that welding is being done.

Propellers of larger diameters and those with heavier sections are another matter. Such propellers cannot be heated sufficiently with the single welding torch and temperature is accordingly brought up by the use of appropriate heating torches. In all except the most exceptional cases, however, when adequate temperature has once been achieved there is no further difficulty of maintaining sufficient heat with the welding torch alone.

The most significant use of preheating occurs in the prevention of stress cracking, or, as it is sometimes called, "season" cracking. This is always a concern in propellers of larger diameters and heavier blade sections.

The American Bureau of Shipping recommends a preheat about 600° F and preferably between 800 and 1000° F for oxyacetylene welding. In the instructions to their surveyors they remark that, as a rule, the higher the preheat, the more sound and trouble-free will be the resultant welds.

The heaviest sections of any propeller are at the blade roots and in the hub itself. These are also the most highly stressed areas, and for that reason it is never recommended that cracks in either the roots or the hub be welded.

Occasionally, however, it is necessary to do so, and it is then that controlled preheating and cooling is applied. Because of the rapid dissipation of heat in and around the hub, great care must be taken to maintain a proper temperature level during the welding process.

Stress Relieving

As mentioned above, stress cracking is a matter of great concern in the repair of large propellers, and preheating is generally used as the means of avoiding such cracking.

In the repair of smaller propellers, however, where rebuilding is much more extensive, the stresses from such extensive welding cannot be averted by preheating. Where there is extensive rebuilding of wasted blades, there result residual stresses that must be relieved after welding has been completed.

In these smaller diameter propellers the stresses seem to be relieved effectively by a general peening of the weld surface prior to grinding. Peening is not used in the larger diameters because effective peening of large blades would be quite difficult, if not impossible. Stress relieving is most desirable after the rebuilding of blades that have been wasted thin and to which unusually large quantities of metal have been added. If the

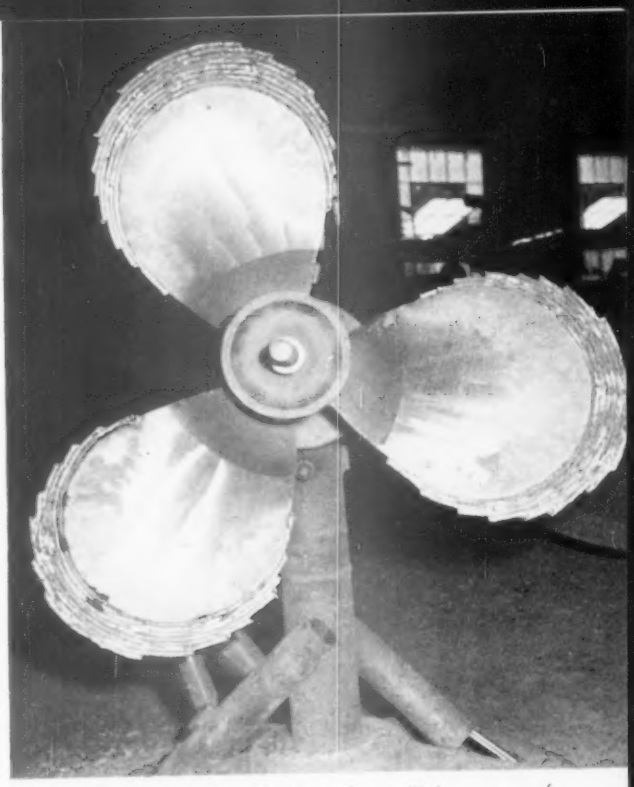


Fig. 4 Restoration of missing area by multiple courses of $\frac{3}{8}$-in. welding rod. Propeller diameter is 44 in.

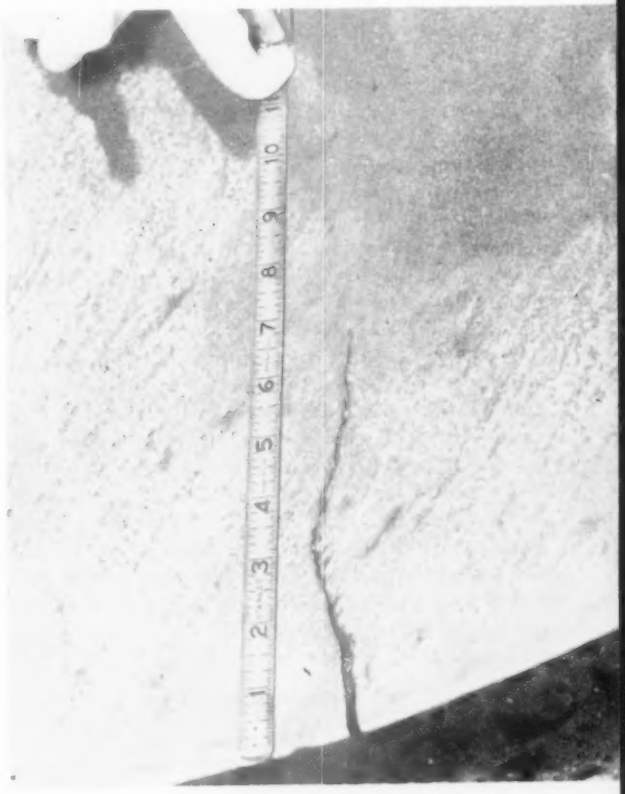


Fig. 5 Typical blade edge crack. Propeller diameter 14 ft 6 in.; weight 16,000 lb. Blade thickness at inboard end of crack is approximately $1\frac{1}{4}$ in.

stresses have not been relieved sufficiently, the results may be seen in small cracks originating at the blade edge and radiating inward. In the case of particularly difficult alloys, an effective and crack-free weld may require preheating, peening and a brief period of post-heating after peening.

It might be remarked that peening seems to serve at least one other useful purpose. When considerable welding has been done over a wide area of a blade there is a general softening of the alloy by perhaps as much as twenty points on the Brinell scale. The vigorous peening of the welded area and the cold working that follows in the straightening process evidently re-crystallizes the metal and restores the worked area to very nearly the original hardness. Also, the same propeller, after having been in service for a period of time, will test very close to the original hardness.

Other Considerations

The primary reason why vessel owners long ago accepted the idea of propeller rebuilding is that it is economical. The cost of the most complete rebuilding is not likely to exceed 25% of the original cost of a new propeller, and the ratio of costs becomes more favorable as the size of the propeller increases.

The quantity of bronze welding rod that can be applied in a unit of time varies with the type and size of the propeller, the nature of the damage, and whether or not welding is being done in the presence of corrosion deposits. A study that took into consideration all sizes of propellers above 24-in. diam was conducted for a protracted period of time. The average application rate for all sizes and for all working conditions was fractionally more than seven pounds per hour of welding.

The purpose of this study was not merely to learn the average application rate but to arrive at a basis for a simple and correct pricing system. Having ascertained the application rate and the consequent cost of material, this cost was added to the known cost per hour of the welder's time. Consumption of oxygen and acetylene was also observed for the same period, and the cost of these materials was expressed in terms of one pound of metal. A study of the operation of grinding the welded area had also been made, and the cost of this labor and material was also expressed in terms of the pound of metal.

When all of these costs were added together the usual factors for overhead and profit were applied and the result became a multiplier. The pricing of the rebuilding portion of the reconditioning operation is done simply by multiplying the number of pounds of welding rod by the multiplier.

Conclusion

The repair and reconditioning of marine propellers does not end with welding. There are problems of grinding, straightening, balancing and finishing, all of which are of interest, but none of which is properly a part of this paper.

There are other methods of restoring torn and broken blades. Other and more modern welding methods have their place in the total work program of a modern propeller repair plant, but none of these things is within the purview of this paper.

This paper attempts to discuss the use of oxyacetylene welding in the rebuilding of manganese-bronze marine propellers. Most of what is pertinent has been said, and there remain only a few comments of a general nature.

It should have been evident throughout these descriptions that much depends upon the welder. This is true. Once he has covered the surface, there is no quick and economical system of inspection by which to locate unwelded voids. The welder must do his work well the first time. Only the sea can stand in judgment of his workmanship.

Training, then, is as much a part of this story as any of the other things that have been said. It is unlikely that any man employed in this work in the writer's plant had even so much as held a lighted torch prior to beginning his work here. In fact, apprentices do not get to hold a torch for quite some time after they begin their work. Each apprentice must first thoroughly understand the characteristics of manganese bronze before he is permitted to weld it. This he does by working first in the grinding, straightening and finishing operations. When he has seen it worked hot and cold and has hammered it and ground it he is introduced to the fundamentals of oxyacetylene welding. When he has learned to use—and to respect—his equipment he begins to work on a "live" propeller.

It is not easy to apply pound after pound of weld metal with uniformity and with no backing, and the confidence of the most confident is sorely shaken when a lump of molten metal falls in a puddle at his feet. Nevertheless, throughout his learning period he is constantly impressed with the fact that the job before him might be the one that damages the company's reputation. There are very few welding errors, indeed.

Barring irreparable impact damage or the complete failure of a blade through fatigue, manganese-bronze propellers have an almost unlimited service life. This service life is enjoyed to the fullest by the vessel operators because of the quick, safe and economical repairs that are possible time after time.

It certainly is true, insofar as manganese-bronze marine propellers are concerned, that an old welding process cheats the sea—again and again and again.

Metallizing of an air seal for jet-engine application

METALLIZING AND ITS APPLICATION IN AIRCRAFT GAS-TURBINE COMPONENTS

Selection of proper spray material, base-metal preparation, spraying technique and machining of deposit are emphasized

BY DONALD E. HACKER

ABSTRACT. This paper is presented to illustrate the use of metallizing on aircraft gas-turbine components. The application of metallizing to aircraft parts requires close control of all phases related to the process. This control is necessary to insure optimum results. The service requirements of the sprayed metal generally are of a critical nature; therefore, in this paper emphasis is placed on the testing methods used to assure satisfactory coatings. The paper discusses specific problems where metallizing was the method used to effect satisfactory solutions.

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Introduction

Metallizing has been used for approximately twenty-

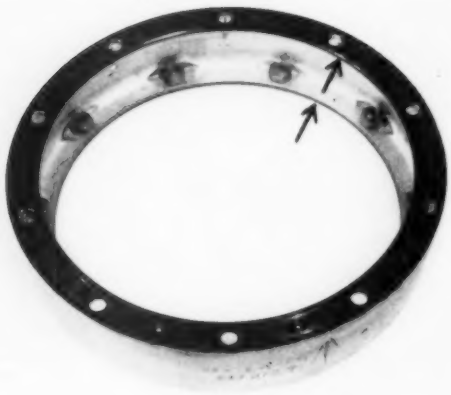
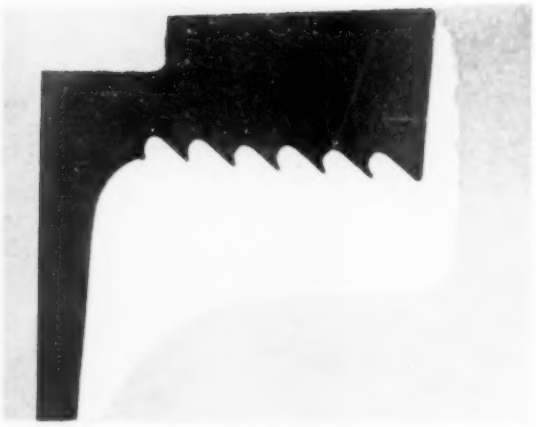


Fig. 1 Rotor spacer diameters restored to print dimensions by metallizing



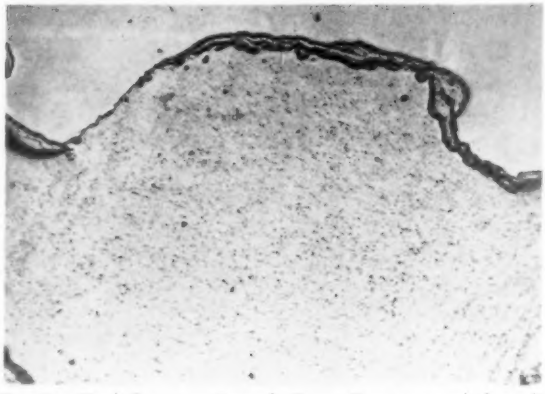


Fig. 2 (*Top*) Cross section of silver-alloy sprayed deposit for wear application. X6. (*Bottom*) Same deposit at higher magnification. Note layer of molybdenum spray at interface. X250. (Reduced by 25% upon reproduction

five years as the "putting on" tool for the repair of worn machinery components and for the salvaging of mismachined parts during manufacturing. Its use was stimulated during the war and limited application of the process was found suitable for aircraft gas turbine components. Today, the variety of metallizing applications employed in the aircraft industry are numerous, with additional uses continually being developed.

Metallizing is the process of spraying molten metal onto a surface to form a coating buildup. Pure or alloyed metal is melted in a flame and atomized by a blast of compressed air into a fine spray. This spray builds up onto a previously prepared surface to form a metal coating. The molten-metal spray is accompanied by a large blast of air; therefore, the object being sprayed does not heat up appreciably and may be referred to as a "cold" process of building up materials. This characteristic, in itself, lends the process to the reclamation of high-temperature alloy components in the fully heat-treated condition where repair by welding with its accompanying high-temperature gradients would adversely affect mechanical properties and part dimensions.

Applications of metallizing to aircraft gas-turbine parts include:

1. *Building Up of Worn or Mis-machined Parts.* The process affords an economical and sound salvage operation for many engine components where functional operation entails a snug or interference fit of mating parts (Fig. 1).

2. *Providing Seals Which Will Wear When Contacted.* To increase engine efficiency by minimizing air leakage, extremely close running tolerances are specified on mating parts requiring a seal material which, when contacted, will wear and not cause seizure or wear of the rotating parts (Fig. 2).

3. *Minimizing or Eliminating Galling of Rubbing Surfaces.* The metallizing process can be employed to hardsurface rubbing areas and prolong part life expectancy. Since fully heat-treated and finish-machined parts can be salvaged in this manner, the application especially lends itself to engine overhaul operations.

4. *Preplacing of Braze Filler Materials.* Brazing, particularly high-temperature brazing, can be enhanced in some instances on high-temperature alloys when preplacing of the filler material is performed by metallizing. Braze flow by capillary action is difficult to obtain on certain alloys. This is not a controlling factor where metallizing is employed, since the braze alloy is sprayed over the entire joint prior to assembly.

5. *Providing Base-Metal Protection from Corrosion and Erosion.* Service life of various jet-engine components can be lengthened provided their surface is protected from corrosive or erosive conditions. When salvaged by metal spraying, materials such as magnesium, aluminum and low-alloy steels are not as susceptible to corrosion or erosion providing the proper metal alloy spray is selected.

Selection of Sprayed Metals

Proper material selection is important in the successful use of the metallizing process. Properties of the deposited metal must be considered when evaluating the

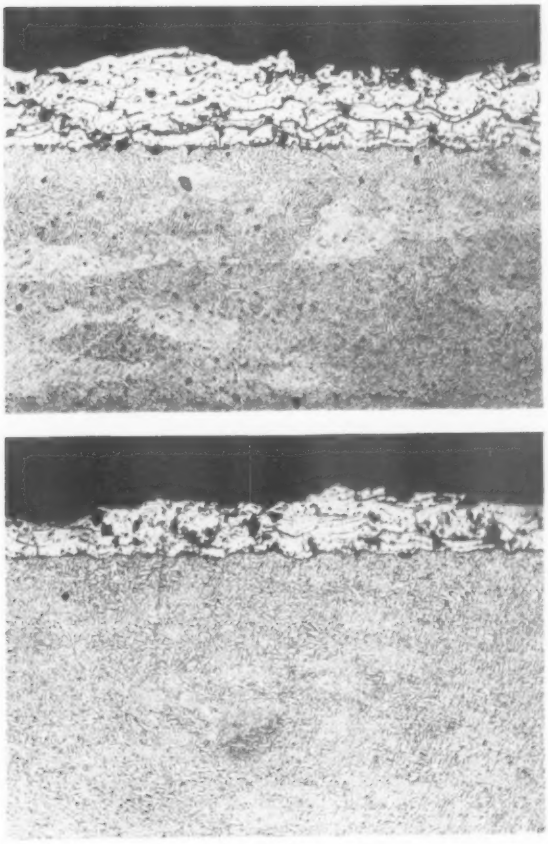


Fig. 3 Sprayed molybdenum on a 12% chrome stainless steel

(Top) As-sprayed. (Bottom) After 15 min at 1200° F in an oxidizing atmosphere. X100. (Reduced by ½ upon reproduction)

suitability for specific engine components, in relation to the service requirements of the components. An example of this is molybdenum which cannot be used on engine components subjected to high temperatures because molybdenum oxidizes at these temperatures as shown in Fig. 3. Of equal importance in evaluating sprayed-metal selection is the effect of chemical or mechanical-cleaning processing to which the part is subjected, either during manufacture or in engine overhaul.

A typical example of this is the spraying of diameters on magnesium-thorium alloys. A molybdenum sprayed deposit bonds well and is ideally suited for salvaging parts with mis-machined diameters. However, after manufacture, the finished part is given an electrochemical protective-coating treatment. The molybdenum sprayed deposit is severely attacked.

Consideration must also be given to machinability of sprayed coatings. Part configurations or availability of special equipment sometimes prevents grinding of sprayed deposits. In this instance, materials with good machining characteristics would be considered.

Metallized deposits do not provide additional strength to the base material and are not considered as part of the cross-sectional area when determining unit stress. The tensile strength of sprayed coatings is usually not a prime consideration except that it is a function of particle-to-particle cohesion and oxide cementation. Sprayed metal particles cool rapidly from their melting temperature during the spraying process, resulting in thermal stresses. Additional stresses are introduced from shrinkage caused by the volume changes occurring during solidification. The magnitude of these internal stresses present in the deposit sometimes governs spray-metal selection. For example, when spraying Type 18-8 stainless steel, cracking may occur in the deposit because high shrinkage stresses are introduced. Conversely, cracking will not occur if molybdenum is sprayed because shrinkage stresses are low.

In general, sprayed materials contain some oxide, are harder, more porous and more brittle than their equivalent in cast or drawn metal. These characteristics, however, make sprayed metal suitable for most aircraft applications on both stationary and rotating parts where interference fits are specified.

Surface-Preparation Requirements

A prime requisite for successful application of the metallizing process is absolute mechanical cleanliness of the surface to be sprayed. Solvents or chemicals leave an invisible but objectionable film on the surface which reduces bonding strength and may even prevent adequate bonding.

Since the majority of metal-spray applications in the aircraft industry do not entail heavy buildup and the coatings are generally placed in compressive loading, grit blasting for surface preparation is sufficient. Previous investigations have shown that fatigue properties are not adversely affected by grit blasting.[1]

On magnesium and aluminum castings requiring metal-spray buildup, the treatment prior to blasting enables the removal of oil, grease or other contaminants from the material by chemical solvents. It has been found that if such parts are immersed in or subjected to oil during service, the oil will penetrate the casting. Grit blasting will not remove this sub-surface oil. If sub-surface oil is present during the spraying operation, a "bleeding" type action occurs as a result of the small amount of heat generated during spraying. The contaminator bled from the porous metal adversely affects the bonding, which can result in flaking or layer separation of the sprayed metal.

Another consideration necessary for successful spraying is the amount of humidity present at the time of spraying. A small amount of condensed moisture on the base metal will reduce the bond strength. To insure that there is no condensate on the work, the flame from the spray gun can be traversed rapidly over the work without the wire feeding, immediately prior to applying the spray deposit.

Metallizing Applications

Typical metallizing applications presently being performed and the methods used for their evaluation are as follows:

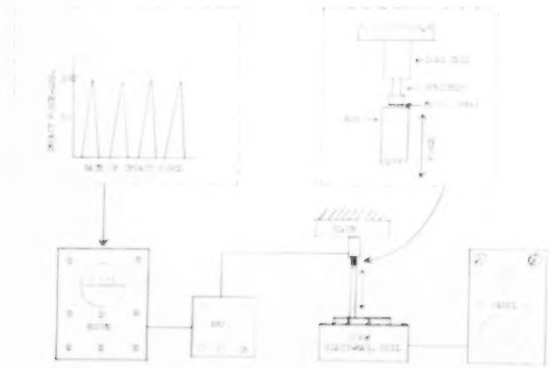
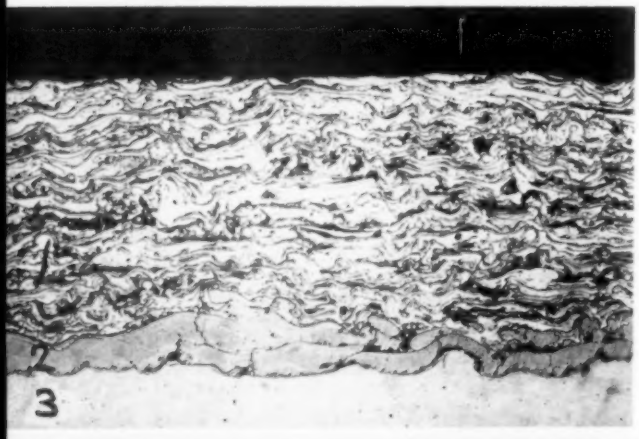


Fig. 4 Schematic diagram of equipment used for evaluating impact forces on metal-sprayed specimens



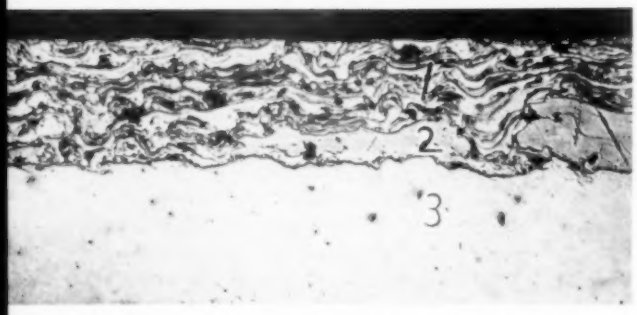


Fig. 5 Cross sections of samples impacted in excess of 1,000,000 cycles at 2000 psi

Code: *1*, sprayed 10% carbon steel, *2*, sprayed molybdenum; *3*, base material. (*Top*) As-sprayed and tested. (*Bottom*) Sprayed, machined and tested

1. *Buildup of Locating Diameters on Low-Alloy Steels.* Most heat-treatable type steels are machined to print dimensions after heat treatment because of distortion occurring during the heat-treating cycle. During this final machining operation, critical dimensions must be maintained. Machining errors can result in the loss of expensive parts unless print dimensions are restored.

A particular engine component when machined on a locating diameter to print, can effect a fit when assembled to its mating component ranging from 0.001 in. interference to 0.009 in. loose on the diameters. The operating temperature of this assembly approaches 900° F at speeds of Mach 2.

To evaluate a metallizing repair procedure on this component, scrap parts were machined 0.040 in. under print diameter. The surfaces were roughened by machining a 250 microfinish. Molybdenum by itself and molybdenum plus 0.10% carbon steel were sprayed respectively on the diameters. The molybdenum-sprayed parts were machined by grinding to blueprint; the 0.10% carbon-steel sprayed parts were machined by turning to blueprint.

The various types of testing on sprayed-deposit samples removed from the engine parts, included destructive chisel testing, oxidation testing at 1000° F, impact testing and microexamination. Oxidation testing of the molybdenum sprayed samples resulted in complete separation at the interface. As a result, molybdenum spray by itself was considered unsatisfactory and further testing was performed only on the double-sprayed coating.

To facilitate impact testing in a special testing rig, $\frac{3}{8}$-in. diameter steel bolts were sprayed with molybdenum and 0.10% carbon steel which became a part of the impact testing device. The heads of the bolts were machined to 0.356 in. diam which gave an area of 0.1 sq

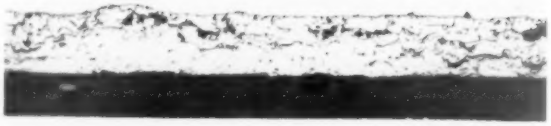


Fig. 6 (*Top*) Turbine wheel with arrow showing metal-sprayed locating diameter. (*Bottom*) Cross section through the sprayed area after 372 hr engine testing

in. Design Engineering specified maximum engine impact loading at 1000 psi. Therefore, an impact force of 100 lb on the bolt head gave the desired loading. Figure 4 shows a schematic diagram of the test setup used.

Testing was stopped after 1,000,000 cycles had been exceeded. No failures occurred on six samples tested with loads averaging 2000 psi. Figure 5 shows typical cross sections after testing. Based on the successful results of laboratory testing, the process was adopted as a repair procedure for similar discrepant parts.

A similar application ideally suited for metallizing is rabbet diameters on turbine wheels. Because of the critical nature of the application, engine cell testing was considered necessary before acceptance of the repair procedure. Figure 6 shows the area sprayed and the cross section through the sprayed area after 372-hr engine cell testing. A composite of molybdenum and Type 420 stainless steel was used for the spray deposit. It was found that when molybdenum was used without the Type 420 stainless steel, the chemical processing applied to the turbine wheel attacked the molybdenum.

2. *Metallizing for Buildup of Wear Surfaces.* Gear journals on engines returned for overhaul occasionally exhibit wear beyond the lower limits of blueprint requirements. When wear is not excessive, chrome plating can be employed to salvage the gears. Appreciable wear results in scrapping the gear.

Since chemical attack of molybdenum is realized in the black oxiding treatment which is given to gears, this spray could not be used, either singly or in a composite.

A scrap gear was machined 0.010–0.015 in. on the journal diameters below blueprint requirements and rough threaded. The areas were blasted with steel grit and sprayed with Type 410 stainless steel. The journals were ground to the proper dimension and processed through the black oxiding chemical treatment without evidence of attack.

To simulate overhaul operations in assembly-disassembly procedures, the gear was immersed in dry ice and permitted to attain a temperature of approximately −40° F. With the gear at this temperature, assembly was made to the mating starter generator bearing and permitted to reach ambient temperature, thereby affecting an interference fit of 0.006 in. on the diameter. The bearing was then removed from the journal by means of a bearing puller. This procedure was repeated five times. Figure 7 shows the gear journals after testing. Subsequent macro- and microexamination revealed satisfactory sprayed structure with good bonding. The procedure was adopted for overhaul salvage based on the satisfactory results obtained.

3. *Providing Seals Which Will Wear When Contacted.* To minimize air leakage, rubbing contact is required between rotating teeth and stationary seals during engine operation. Seal materials are required to possess relative softness and good wearing characteristics at service operating temperatures.

The testing performed to evaluate seal materials consists of depositing the required thickness of sprayed metal on brake-shoe type specimens. The sprayed specimen is positioned in a testing fixture with rotating teeth fed into the sprayed deposit. Macro- and microexaminations are subsequently performed on the specimen and the rotating teeth. Pickup of sprayed material on the rotating teeth cannot be tolerated since unbalance of the rotating parts would result. Corrosion and oxidation tests are performed on samples sprayed with ma-

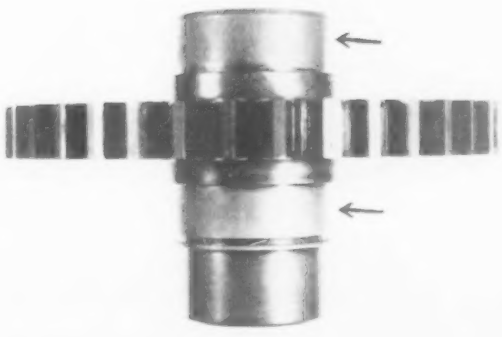


Fig. 7 Gear journals salvaged by metal spraying

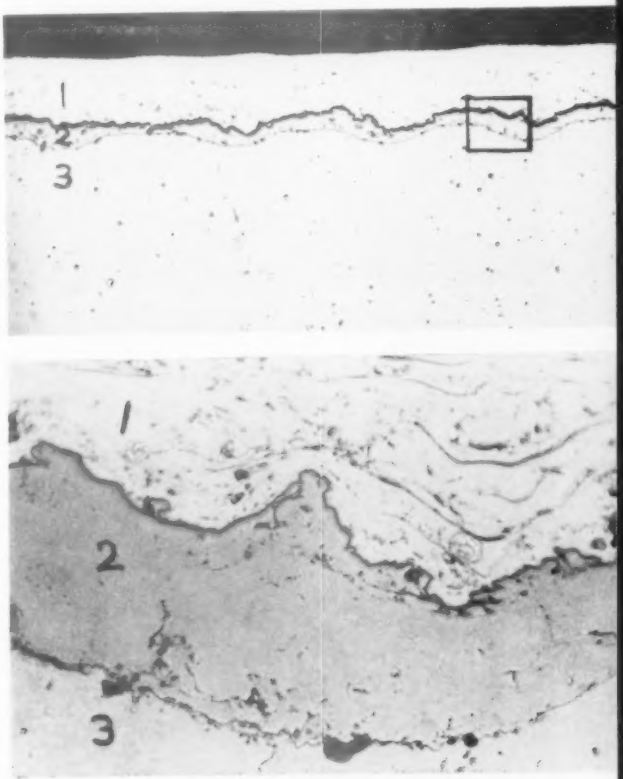


Fig. 8 (*Top*) Cross section showing the appearance of a defect between silver-alloy deposit, *1*, and molybdenum, 2. X50. (*Bottom*) Section of top picture at X500 magnification. Note that no defect is present. (Reduced by 1/3 upon reproduction)

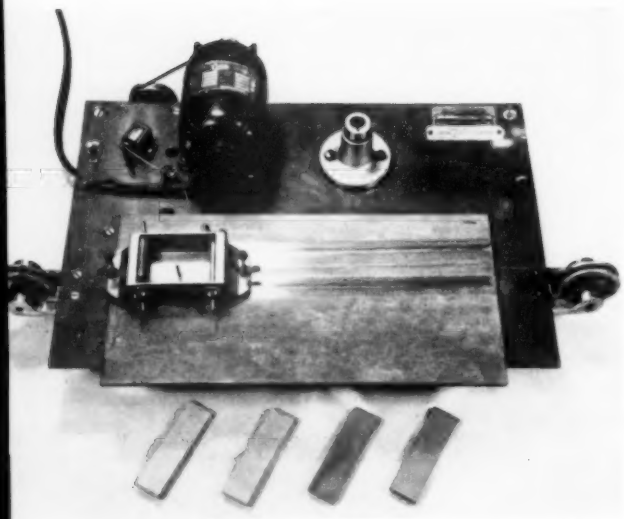


Fig. 9 Test apparatus used to evaluate wearing characteristics of metallized coatings

terials showing promise from the brake-shoe test. Engine cell testing is required before any material is recommended for use.

A misleading observation occurs upon evaluation of soft coatings. Automatic or hand polishing on mounted metallographic samples indicates a complete separation or heavy oxide band between the soft spray and molybdenum spray when examination is made at low magnification (up to × 50), as shown in the top view of Fig. 8.

Observation of this indication at higher magnifications shows a satisfactory sprayed coating. This condition is caused by preferential removal of the soft spray deposit adjacent to the hard molybdenum (approximately R_c60.) This region is not in focus at lower magnifications.

4. *Eliminating Galling of Rubbing Surfaces.* Fretting corrosion is sometimes encountered between mating components resulting in localized wearing. Relative movement between mating parts also causes wearing.

One area consistently exhibiting excessive wear was a ball joint coupling. It was felt that hard surfacing applied to the areas exhibiting wearing would minimize or eliminate this condition. Some methods considered for hard surfacing the coupling included welding, high-temperature brazing and powder metallizing. These processes, however, require heating to high temperatures to accomplish fusion and could not be used because of resultant distortion and loss of mechanical properties in the base material.

Molybdenum spray deposits, when evaluated on sample parts, showed satisfactory results. There was no evidence of wear or fretting corrosion when a ball joint coupling was sprayed and engine tested for 150 hr. Based on the results obtained, the process was adopted not only for overhaul salvaging, but the manufacture of parts. A test setup used to evaluate coatings for this or similar applications on a screening type basis is shown in Fig. 9.

Summary

Aircraft gas-turbine components which can be salvaged by the metallizing process are subjected to various types of tests based upon their expected operation in service and cleaning cycles used in engine overhaul.

Emphasis is placed on all phases relating to the process to insure optimum results. This includes selection of the proper spray material, base-metal preparation, spraying technique and machining of the deposit.

Metallized deposits do not appreciably increase the mechanical properties of the base metal. Strength of sprayed components therefore, are calculated from the cross-sectional area of the base material excluding the cross section of the sprayed deposits.

The majority of applications for metal spraying are locating or bearing diameters where the sprayed deposits are placed in compression in the engine assembly. Because of its effectiveness in salvaging expensive components, metallizing is becoming recognized as an essential tool in the manufacture and maintainability of aircraft gas turbines.

Acknowledgment

John Hines—Production Engine Department Laboratory, General Electric Co.

Reference

1. Williams, W. L., "The Effects of Metallizing Procedures on the Fatigue Properties of Steel," 1949 Preprint by the ASTM.

Practical Welder and Designer

POWDER LANCING CLEARS WAY FOR NEW RADIATION LAB

Powder lancing recently speeded a huge concrete demolition job for General Electric Co.'s General Engineering Laboratory, Schenectady, N. Y. The Laboratory's Building 258 formerly housed a high-speed pit having concrete safety walls up to 4 ft thick for testing steam turbines. Part of the building is now being converted into a new million-dollar radiation laboratory scheduled for completion in 1958. Before construction could get under way, however, the walls had to be modified and over 8000 cu ft of concrete removed.

The most economical and practical means of doing this was by powder lancing, an outgrowth of the powder-cutting process first introduced in 1943 for cutting stainless steel. Today, powder lancing is widely used in the steel industry for producing shot holes in open-hearth furnace slag pockets. However, due to recent apparatus developments and new operating techniques, it is now practical to cut thick concrete—especially where mechanized demolition methods are too costly, where time is an important factor, and where blasting cannot be employed. With the powder lance, concrete may be demolished in huge sections, moderate sized boulders, or smaller pieces—as conditions require.

In powder lancing, a mixture of iron and aluminum powder is fed pneumatically into a lance handle and mixed with oxygen. The lance itself is manually operated and consists of a lance handle with one or more lengths of black-iron pipe attached. The powder and oxygen are mixed in the lance handle, carried to the cut by the pipe, and produce a bombardment of burning iron and aluminum particles which melts the concrete (Figs. 1 to 5). Cuts in concrete 12 ft thick have been made with the lance, but theoretically there is no limit to the depth of the powder lance's cut.

Here's the part that powder lancing played in paving

Based on a story by the Linde Co., New York, N. Y.

Fig. 2 Having completed a 16-ft vertical cut (left center), the operator now swings into a horizontal cut that will measure 20 ft

Fig. 1 Here's the powder lance in action making a vertical cut in concrete 3 ft thick. The concrete safety walls are being cut into 18-ton sections for removal by crane

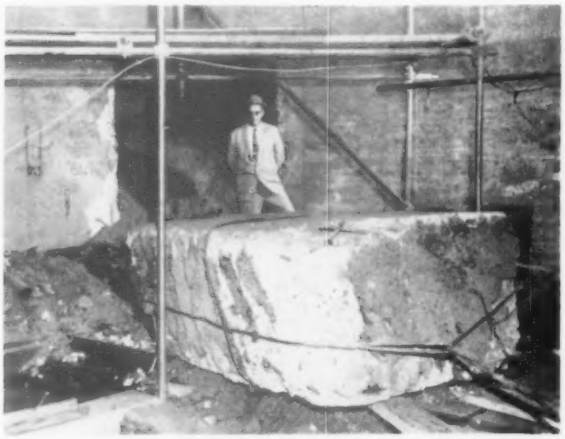


Fig. 3 This massive concrete section—the first severed from the test pit's safety walls—is ready for disposal

Fig. 4 A close-up of a typical powder-lance handle. Equipped with one or more lengths of black-iron pipe in its holder, the powder lance will produce clean cuts in concrete and reinforced concrete over 12 ft thick

Fig. 5 A powder dispenser is used in powder lancing to deliver the required amounts of powder at a uniform, accurately-controlled rate. This dispenser's powder capacity is 200 lb

the way for General Electric's new radiation laboratory.

The turbine testing pit was shaped hexagonally and consisted of two concrete safety walls separated by 6 ft of packed sand. The inner wall was 3 ft thick, and the outer wall 4 ft thick. Both walls stood about 16 ft high. A large amount of this concrete had to be removed to meet the construction specifications for the laboratory.

Using the powder lance, the concrete walls were cut into huge sections measuring 20 x 16 ft and weighing up to 18 tons apiece (Fig. 3). Cutting speed was about $1^1/_2$ ft per hr. After each of the sections had been severed, it was hoisted out of the pit by a 100-ton bridge crane and hauled away.

PRODUCTION TIME CUT

BY ROBERT HULL AND GLENN HARTWICK

Improved quality and reduced costs through faster production are the results of an unusual tungsten-arc welding machine installation devised by the Kitchen Machine Division of the Toledo Scale Co., Rochester, N. Y., for the fabrication of their Toledo door-type dishwasher with electrical push-button controls.

One of the most interesting operations is the assembling of the dishwasher's stainless-steel tank. This sixteen gallon tank of 18-8 Type 302 stainless steel is 30 x 30 x 16 in. deep and is made by welding two tank ends to a "U" shaped tank section—a total of three seams to be welded on either side with a butt joint. To produce a high-quality weld, the inert-gas-shielded tungsten-arc process was selected to replace a metal-arc lap joint and solder fillet.

The unusual setup consists of a 300-amp arc welder together with a carrying machine and two machine holders combined electrically to actuate simultaneously the carrying machine, argon, water, high frequency and welding current.

The welding fixture comprises a main frame, supporting a water-cooled chill-bar frame to which the wrap-around and two sides are clamped with approximately four tons pressure. Overhead is a truss supporting the carrying machine and torch assembly.

The machine welds along one seam, using one holder, and on reaching the end of the seam the current is thrown to the holder on the other side of the arm and the seam completed in the opposite direction. The three

R. Hull is Supervisor of Methods Department associated with the Toledo Scale Co., Rochester, N. Y., and G. Hartwick is Process Engineer associated with the Air Reduction Sales Co., Buffalo District.

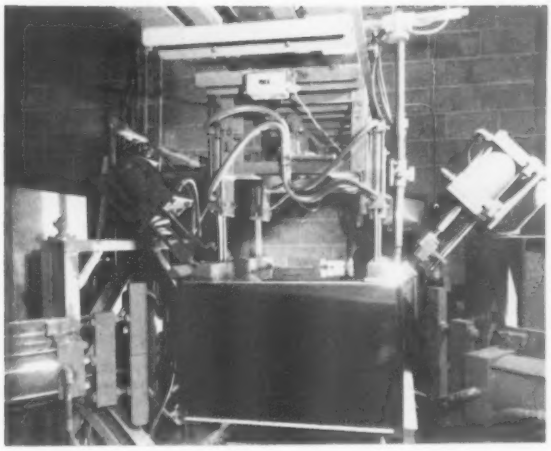


Fig. 1 View of a stainless-steel tank being welded automatically by the tungsten-arc process

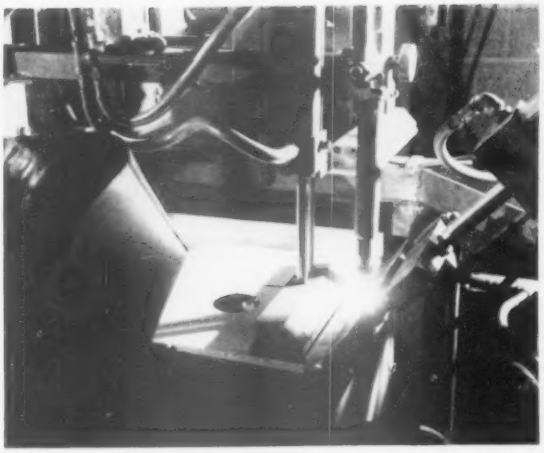


Fig. 2 Close-up of machine tungsten-arc electrode holder welding tank's end-seam

seams per side are welded as the fixture is pivoted through 180 deg.

Toledo's unique combination of standard equipment has resulted not only in a 60% reduction of time but also in an improved quality of weld and the elimination of grinding.

CONSUMABLE INSERTS USED IN WELDING MISSILE AIR TANK

Consumable weld inserts used to join the ends of the guided-missile air tank shown in Fig. 1 helped Research Welding & Engineering Co., Compton, Calif., save weight and resulted in X-ray quality welds of exceptionally high strength. The tank, 60 in. long by 30 in. diam, has to contain air under 3000-psi pressure and yet weigh less than 600 lb. Use of the consumable inserts eliminates both the need for and the weight of backing rings. In addition, they allow welding conveniently from one side only.

With the consumable-insert process, a ring of carbon steel, low alloy, or stainless steel with a specially designed cross section, is placed between the metal sections to be joined.

Inserts of 1722-AS material are used to make the root passes joining the $\frac{1}{4}$-in. thick heads to the $\frac{5}{16}$-in. thick body of this SAE 4335 steel air tank. After proper joint preparation, the root pass is formed by fusing the insert with automatic inert-gas-shielded tungsten-arc equipment. More frequently, the root-pass welding is done manually with an inert-gas-shielded tungsten-arc torch. After finishing the root pass, the joint is completed by submerged-arc welding using low-alloy high-strength wire. Heat treatment of the weld metal develops a tensile strength of over 200,000 psi to match that of the base metal.

Fig. 1 Ends of this guided-missile air tank were joined by means of the consumable weld-insert process

Based on a story by the Arcos Corp., Philadelphia, Pa.

Society News

Bennett Cerf to Speak at President's Reception in St. Louis

Bennett Cerf, famed publisher, columnist, raconteur and star of TV's "What's My Line?" will be the keynote speaker at the SOCIETY's annual banquet at the Hotel Statler, St. Louis, during the 39th Annual Meeting and Welding Show. Mr. Cerf's topic will be "Changing Styles in American Humor."

The dinner, which takes place Monday evening, April 14th, is one of a series of gala events and educational meetings which is expected to draw thousands.

The dinner will follow immediately after the annual President's Reception, long recognized as the SOCIETY's outstanding social event of the year. It gives each member the opportunity to meet personally with all the officers of the SOCIETY.

A. Carl Weber, vice-president in charge of research, Laclede Steel Co., St. Louis, will serve as toastmaster, according to David S. Lewis, dinner committee chairman.

The week-long events will be started with the convening of the annual meeting, at which the President's report will be given, new officers elected and awards made. The delivery of the annual Adams Lecture by Dr. Ernest F. Nippes, of Rensselaer Polytechnic Institute, whose paper is titled, "The Weld Heat-Affected Zone," will conclude the morning's activities.

In the afternoon, the 39th Annual Meeting will get under way with an extraordinarily diversified program, both in terms of subjects covered and geographical distribution of speakers. Ninety-five authors, drawn from 15 states and Canada, will present 63 papers in 21 sessions. The American Society of Mechanical Engineers' Metals Engineering Division will co-sponsor four of the sessions.

On Tuesday, the biggest Welding Show ever staged will open for a three-day run at Kiel Auditorium. It will represent the largest collection of welding equipment and accessories ever gathered under one roof. Virtually all of the equipment will be demonstrated under simulated factory conditions. Also at Kiel Auditorium, Tuesday will be the annual Informal Panel Discussions which deal with practical problems of welding. Entitled "Practical Shop Problems," this will be an informal session at which "experts" familiar with welding and related phases of shop operations will briefly discuss modern industrial plant operations and then, in an open forum, help the members of the audience solve their shop problems in a practical manner. Ted B. Jefferson, editor and publisher, *Welding Engineer*, will be in charge of this activity.

Special educational lectures will be held at the Hotel Statler late in the

BENNETT CERF

Bennett Cerf, nationally known TV panelist, publisher and columnist, will speak at the Society's banquet on Monday evening, April 14th, at the Hotel Statler in St. Louis

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afternoons of Monday and Tuesday. Professor Earl R. Parker, of the University of California, will address both sessions. His topic will be "Engineering Behavior of Welded Structures."

Visitors will also have the opportunity of visiting two plants in the St. Louis area. On Wednesday, April 16th, they will see the A. O. Smith Corp. plant in Granite City, Ill., where automobile bodies are fabricated.

This tour will have special interest because visitors here will see for the first time the mass production assembly line of the all-welded 1958 model Chevrolet automobile body frame.

On Thursday, April 17th, the tour will cover the Midwest Piping Co. which is a leading prefabricator of welded power-plant piping and pipe fittings. Interesting examples of modern welding procedures will be shown. En route from the plant, there will be a stop at Anheuser-Busch, where a tour of the plant facilities will be made.

A four-day ladies' program also has been arranged. Among the highlights will be a luncheon, tea and bridge party at Stix-Baer & Fuller department store; cocktails and luncheon in St. Louis' famous Frontier Room of the Montclair; shopping tours; theater matinee; conducted tour of the St. Louis Art Museum; luncheon in the Indian Gallery of the museum; visit to the Jewel Box floral display in Forest Park and a conducted tour of St. Louis' Plaza area, which will include the levee and riverfront, the Old Cathedral, Soulard Market, Shaw's Gardens, luncheon at Stan Musial's and Biggie's Restaurant, and Grant's Farm.

On Thursday, April 17th, a Sustaining Members' luncheon will take place at the Hotel Statler. The keynote speaker will be James F. Lincoln, chairman of the board of the Lincoln Electric Co.

Hotel reservations may be made by writing to the Housing Bureau at the SOCIETY's headquarters.

Four Companies Enroll as Supporting Members

Four more companies have been enrolled with Supporting Company memberships in the AMERICAN WELDING SOCIETY.

With enrollments effective as of Jan. 1, 1958 are: J. E. Haseltine & Co., 115 S. W. Second Ave., Portland, Ore.; Peden Steel Co., 512 W. Hargett St., P. O. Box 9514, Raleigh, N. C.; and Vickers, Inc., Electric Products Division, 1815 Locust St., St. Louis 3, Mo. With an effective enrollment date of Feb. 1, 1958, is E. R. Joseph Co., Inc., P. O. Box 189, Norristown, Pa.

DR. COMFORT A. ADAMS

AWS FOUNDER

PASSES ON

Dr. Comfort A. Adams, founder and first president of the American Welding Society, *died at his home in Philadelphia on Friday night, February 21. He was 89 years old.*

Memorial services were held at 2:00 P.M. on Tuesday, February 25th. Six members of the Board of Directors of the AWS including the President, the Junior Past-President, the National Secretary and Assistant Secretary were present. Some 75 friends and co-workers of Dr. Adams joined in paying their last tribute to this great engineer.

Printer deadlines prevent us from publishing additional details at this time, but a complete coverage will appear in the April Journal.

THE EDITORS

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Hobart Assumes Sustaining Membership

Hobart Brothers Co., Hobart Square, Troy, Ohio, has become a Sustaining Member of the AMERICAN WELDING SOCIETY, effective Jan. 22, 1958.

They manufacture a complete line of arc welders, electrodes and accessories. Welders include: d-c motor generators, engine-driven models with liquid-cooled, air-cooled or diesel engines; self-propelled mobile welders; a-c transformers; d-c rectifiers; a-c/d-c combinations; inert-gas arc welders; d-c belt-drive generators; constant-voltage CV welders; equipment for automatic and semiautomatic welding using submerged-arc flux or inert gas. Electrodes produced are mild steel, low alloy, low hydrogen, stainless steel, hard surfacing, cast iron, fluxes and wire for automatic welding. Welding accessories include colored plastic headshields, electrode holders, protective clothing, cable, etc. Induction heaters, 800 cycle, for stress relieving, special generators for carbon-air cutting and gouging, stud welding and other special applications are also available. Outlets and distributors in all principal cities, domestic and foreign.

W. H. Hobart, Jr. is the Sustaining Member representative.

Acro Welder New Sustaining Member

Acro Welder Manufacturing Co., 1719 W. St. Paul Ave., Milwaukee 3, Wis., has become a Sustaining Member of the AMERICAN WELDING SOCIETY.

Welding engineers and welding machinery manufacturers, they build a wide range of resistance and production welding machinery including "Acro" standard spot, projection, butt and seam-resistance welders and brazers; and "Acro-Magnetic" magnetic force spot and projection resistance welders; and "Acromatic" multihead and special purpose automatic resistance welders; and special purpose production welding machinery employing automatic arc and gas welding processes.

The Sustaining Member representative is Thomas B. Wilson

Forms for I.I.W. Meeting

Individuals interested in obtaining copies of Circular No. 2 and the enrollment forms for the 1958 Annual Assembly of the International Institute of Welding in Vienna, Austria, from June 29th to July 6th, are urged to write to the Office of the American Council of the International Institute of Welding, 29 W. 39th St., New York 18, N. Y. All individuals desiring these forms must be approved by one or more of the organizations involved, namely: AWS, WRC or Ship Structure Committee.

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LOW-, MEDIUM- AND HIGH-CARBON STEELS Pitfalls of welding low-, medium- and high-carbon steels	*Thursday, February 27*
ALLOY STEELS Alloying elements need not make your welding complicated	*Thursday, March 6*
STAINLESS STEELS How to increase efficiency in stainless-steel welds	*Thursday, March 13*
CAST IRON AND CAST STEEL Quality repairing and welding of castings	*Thursday, March 20*
LIGHT METALS Successful welding of light metals	*Thursday, March 27*
COPPER AND NICKEL BASE ALLOYS Correct know-how makes these alloys easily weldable	*Thursday, April 3*

PLACE: Metcalf Auditorium—Brown University
Waterman and Thayer Sts.
Providence, R. I.

MEETING TIME: 7:30-9:30 P.M.

COST: The cost of the complete series for AWS members is $3.00. For nonmembers the cost is $7.00 of which $4.00 will be applied to the first year's dues if the nonmember joins the AWS before the end of the lecture series.

Application forms for the lecture series may be obtained by contacting Allen Olson, BIF Industries, Inc., 345 Harris Ave., Providence, R. I. Telephone: GAspee 1-4302. Home Phone: REgent 7-1768.

Santa Clara Valley Section to Sponsor Welding Show

The Second Welding, Brazing and Heat Treating Show sponsored by the Santa Clara Valley Section of the AMERICAN WELDING SOCIETY will be held in San Jose, Calif., on March 27th, 28th and 29th. The Show is timed in cooperation with the First Western Welding, Brazing and Heat Treating Conference sponsored by the Golden Gate Chapter of the American Society for Metals, to be held on March 27th and 28th at Stanford Research Institute in nearby Menlo Park, Calif.

The Second Welding Show will be staged in the 48,000-sq. ft. Santa Clara County Exposition Hall at the county fair grounds in South San Jose. This show, of educational nature, meets the demand of the welding and metal-working industry in the San Francisco Bay area of California and the surrounding territory. The successful First Show was held two years ago at San Jose State College. The demand from industry and the exhibitors has been for a larger show with more space, more demonstrations and a show of longer duration.

The show is expected to attract several thousand people. Exhibitors are expected to number 45 to 50, including most national name manufacturers of welding equipment. This is a "working show" featuring many live displays and demonstrations of all welding processes, including weld inspection, heat treating and allied metal working tools. There will be displays of welding equipment, tools, supplies and safety goods. There will be a photographic display of large welded products from the area; also an exhibit of heavy weldments and welded machinery made in the Santa Clara Valley.

Some of the very latest welding processes will be demonstrated. They include the magnetic-flux arc process, tungsten-arc cutting of nonferrous metals, automatic oxyacetylene hard surfacing, refinements in CO_2 welding, automatic constant-voltage arc welding; the last word in inert-gas metal-arc welding and inert-arc spot welding; newest type inert-arc torches; latest in welding supplies and welding safety goods. All welding people, instructors and students are invited to attend this free show. Admittance is by registration on arrival.

Saxe Becomes Sustaining Member

Saxe Welded Connections, 1701 St. Paul St., Baltimore 2, Md., are now Sustaining Members of the AMERICAN WELDING SOCIETY. Saxe Welded Connections are sales representatives for Saxe Welded Connection units used in assembly of welded steel structures and manufactured by J. H. Williams and Co., Buffalo 7, N. Y.

The Sustaining Member representative is Van Rensselaer P. Saxe.

A Boost for AWS

Sixty-one technical representatives of the Eutectic Welding Alloys Corp., Flushing 58, N. Y., have become members of the AMERICAN WELDING SOCIETY, as a result of a recent company-sponsored membership campaign.

Aware of the importance and contributions of the AWS to the advancement of the science of welding, Eutectic has sparked a campaign through bulletins and meetings to encourage its technical representatives all over the country to join.

Rene D. Wasserman, president of Eutectic, said: "We are very grateful to be able to report that 61 of our technical representatives have joined AWS in recent weeks." This brings to an all time high the number of Eutectic technical representatives who are now members of the AWS.

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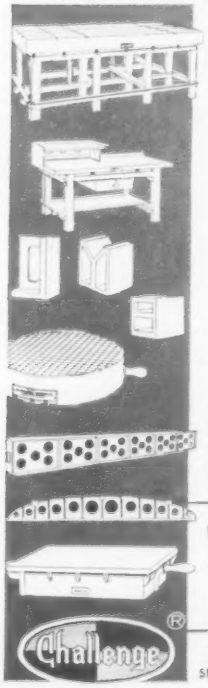

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THINGS YOU SHOULD KNOW

(That Happened in January)

● Early in January, J. D. Chodrow joined your headquarters staff as assistant to Technical Secretary Fenton, filling a position which had been open since former Secretary Greenberg left the SOCIETY to join the staff of Westinghouse Electric Corp.

● Art Phillips, in addition to his handbook and educational activities, is preparing a new film directory (with the able help of Prof. R. C. Wiley) and a new Speaker's Directory which will include suggestions for "Informational Talks" suitable for presentation to civic groups, service clubs, fraternal organizations, management forums and professional groups including architects and structural engineers, in addition to the more technical talks usually presented before AWS Sections and engineering and vocational school students.

● With the generous assistance of manufacturers and fabricators, your Secretary is assembling a small library of 35-mm color slides showing important new and dramatic applications of welding. These are being used for a series of nontechnical talks designed to illustrate the economy, safety and almost universal applicability of welded fabrication.

● On January 6th, R. D. Thomas, Sr., and R. T. Brown, representing a special committee of NEMA, conferred with your EAC Chairman Clarence Jackson, Art Phillips and your Secretary about the possibility of AWS distribution to college professors and students of material covering welding processes and welded joints suitable for inclusion in all types of design courses. Preparation and printing of the material is being financed by NEMA.

● On January 8th, your staff members held a conference with representatives of Air Reduction Co. concerning the revision, printing and distributing by the SOCIETY of training and design manuals originally prepared and published by that organization. More recently the SOCIETY has been requested to consider publishing a manual covering the welding of aluminum alloys. These are apt illustrations of the increased activity of your SOCIETY in the general field of education.

● Assistant Secretary Mooney traveled to St. Louis during the evening of January 8th together with Convention Chairman Ed Dato, who spoke before the St. Louis Section, January 9th. Both Frank and Ed conferred with Local Chairman Gillerman and his associates who are responsible for all local arrangements for our annual spring meeting and welding exposition to be held April 14–18 in Hotel Statler and Kiel Auditorium in St. Louis. Special events will include the President's Reception; the Annual Dinner (Bennett Cerf of "What's My Line" will be feature speaker); ladies' special program; two plant inspection trips; Sustaining Members luncheon with J. F. Lincoln as speaker; RWMA, NWSA, WRC and many other special breakfast, luncheon and dinner events.

● During the night of January 8th, your Secretary flew to Seattle to join President Sander for a series of meetings with District 10 and 11 Sections. With Larry Hamilton as host we joined Hank Haines, Frank Soady, Prof. G. Schaller and C. M. Styer for lunch at the Ranier Club. Later through the courtesy of Past-Director Styer we visited the plant of Pacific Car and Foundry Co. before meeting Jim O'Brien, Ralph Templeton and D. M. Allan for a drive to Tacoma where the dinner meeting of the Puget Sound Section was held at "Top of the Ocean." Following talks by President Sander and your Secretary, with Chairman S. T. Viggers in charge, the large group visited the Tacoma plant of American Smelting and Refining Co. where Gen. Supt. C. R. Low organized a complete and informative inspection of all facilities. At midnight, in spite of a "mist" which persisted throughout the day and evening, we finished a full but completely enjoyable day at the Washington Athletic Club.

● The following morning we were met on arrival at the Portland airport by O. Focht, vice chairman, and H. Watt, treasurer, who drove us to the Columbia Edgewater Country Club where a luncheon and conference were held with nine leaders of the Portland Section, including Chairman P. L. Buck and Secretary G. Siegner. The conference was followed by an interesting inspection of Portland and its industries.

● On January 14th, following early morning plane flights, President Sander and I were met at Albuquerque airport by Section Secretary V. G. Nelson. Afternoon activities included an inspection of A. T. and S. F. Railroad Co. shops at the invitation of J. J. Flowers and through the courtesy of Supt. C. F. Lewis and General Foreman L. W. McClelland with whom we had interesting conferences; an interview with a newspaper reporter; and a visit at Hilton Hotel with Mr. Groth, active in the Section since its formation. The dinner meeting was held at the Chinese Village (excellent steak dinner), following a social period and with Chairman Prof. A. P. Bailey and Vice-Chairman W. H. O'Brien in charge. President Sander discussed SOCIETY activities and objectives and your Secretary presented a semitechnical talk, "Welding Achieves New Firsts." An after-meeting session carried through until 1 A.M. to conclude another busy and profitable day.

● Manager F. M. Aspey of Consolidated Western Steel Division's Phoenix plant met us at the airport the next morning and conducted us on a tour through the plant before acting as host for lunch at one of the more famous Phoenix restaurants. The dinner meeting was held in the Sky Room of the new Sahara Hotel with Chairman A. V. McEowen and Vice-Chairman John Mafico in charge. O. T. Barnett of Armour Research Foundation gave a technical discussion following brief talks by President Sander and your Secretary.

● Los Angeles Section Vice-Chairman John Ross and Aircraft and Rocketry Chairman Leo West were waiting to take pictures as President Sander and I left the plane the next morning for two very busy days which included a luncheon and conference with the Executive Committee of the Los Angeles Section in the Trojan Club Room at the Biltmore Hotel; an inspection of facilities at the Biltmore and at the Great Western Exhibition Hall with Exposition Manager Kenworthy; the social hour, dinner and meeting of the Los Angeles Section at Elks Lodge in Huntington Park with Chairman Dave O'Connor presiding and talks by President Sander and your Secretary; inspection of facilities of Hotels Statler and Ambassador, and of Shrine Exposition Hall and Pan Pacific Auditorium and Exposition Hall, with lunch at the Hollywood Roosevelt Hotel; a visit to the Vernon plant of Consolidated Western which is headquarters for President Sander; and finally the dinner meeting of the Long Beach Section at Eaton's Chicken House with President Sander furnishing transportation and returning your Secretary to his hotel at midnight following the program which included a "coffee talk" by humorist Clarence Crary, remarks about the SOCIETY by President Sander and a technical presentation by your Secretary with Chairman Ray Davenport in charge and District Director C. L. Breese, Secretary V. Buster, Vice-Chairman A. H. Butler and Program Chairman J. S. McClure assisting.

● District Director C. B. Robinson and San Francisco Section Chairman C. W. Doggett welcomed us to that city and to the dinner meeting at Spenger's Fish Grotto in Berkeley where we both spoke at a well attended meeting and met many leaders of this group including

Past-Chairmen Fred Stettner and W. F. Ajello.

● Following lunch, the next day, at the Fairmount as guests of District Director Robinson, we were driven to South Palo Alto via the Skyline Drive by R. N. Skow. The Santa Clara Valley Section held their dinner meeting at Hal's Restaurant with a dinner choice of three entrees and with talks as for the other meetings. Chairman M. J. Sebastian presided and was supported by fellow officers A. M. Hubbard, R. N. Skow, F. Nelson, J. Grafton and V. S. Zacharenko.

● An interesting visit with G. D. Williams and an inspection of the South San Francisco plant of Consolidated Western preceded a flight to Sacramento where Secretary R. E. Labagh acted as host and Chairman Paul Jonas presided at another excellent meeting with San Francisco Section Chairman Doggett and Director F. H. Stevenson in attendance.

● The following day President Sander returned to Los Angeles while I enjoyed a pleasant ride from San Francisco to San Luis Obispo with C. W. Doggett. At California State Polytechnic College I had conferences with Prof. R. C. Wiley and Engineering Dean H. P. Hayes, and then, following dinner with a group of faculty members, addressed a very large group of students interested in engineering and agricultural applications of welding. The evening meeting was followed by a reception at Prof. Wiley's home for those students active in the AWS Student Chapter, including officers Bill Walker, John Morgian and Jim Miller.

● Chairman Ray Potts and Secretary Joe Roberts welcomed President Sander and your Secretary to Salt Lake City on January 28th for a dinner meeting at Temple Square Hotel following a tour of the area during the afternoon. This outstanding meeting marked the end of our successful western tour. Following a long evening I caught a 2 A.M. flight east for Chicago leaving President Sander waiting at the airport for a 3 A.M. flight west for Los Angeles.

● At each stop we found generous hospitality, genial fellowship, keen interest in and enthusiasm for Society activities and a sincere desire to increase the understanding and use of welding. To all those who made this strenuous trip so pleasant and productive, President Sander and I extend greetings and our sincere thanks.

● Returning to Chicago your Secretary participated in the two-day Midwest Welding Conference sponsored by Armour Research Foundation and organized by Harry Schwartzbart. This was the fourth annual conference with twelve outstanding technical papers covering a variety of timely subjects and about three hundred men from industry in attendance.

● Back at headquarters on January 31st to meet with S. T. Walter, A. L. Seiden and E. DiLiberti, 1958 Tellers of Election, for their canvas of nomination ballots for 1958-59 National Officers, Directors and Members of the Nominating Committee. Since no "write-in" nominations numbered more than two for any individual (100 required), all official nominees of the national and district nominating committees were elected without a second ballot.

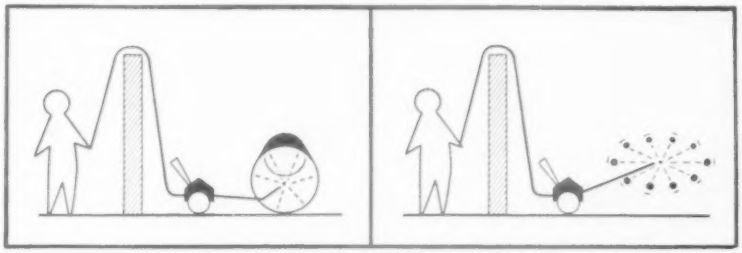
Fred L. Plummer

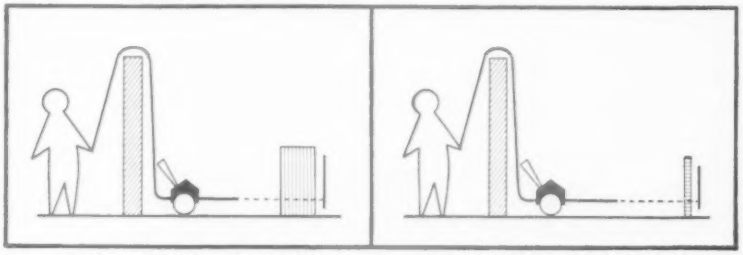
PLAN TO ATTEND

AWS NATIONAL SPRING MEETING

APRIL 14-18, HOTEL STATLER

ST. LOUIS, MO.





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EDUCATIONAL ACTIVITIES

Welding Education Through "Official Speakers' Directory"

One of the most important projects undertaken by AWS sections is the scheduling of speakers for the technical sessions at the monthly meetings. Obtaining speakers is sometimes difficult, it is often frustrating and it is almost invariably time-consuming. The importance of this task cannot be underestimated since the success of the meeting depends upon the speaker. If his subject is well chosen and his talk is slanted to the needs of his audience, the evening will be successful. The subject should have local appeal and be within the technical understanding of the audience.

Each individual member attends section meetings with some objective in view. This objective may vary considerably according to his occupation, position or educational background. One thing each has in common—a sincere desire to gain something from the talk given at the technical session.

Technical Speakers

Generally speaking, there are two means of obtaining speakers: by recommendation or through the medium of a Speakers' Directory. Both methods have merit. With a recommendation to guide him a program chairman feels reasonably safe in issuing an invitation. One disadvantage of this method is its limitation. A popular speaker is likely to receive so many requests that he cannot possibly fulfill them all. Furthermore, this method limits the program to the specific subjects covered by the recommended speakers. It also denies the younger members the opportunity of being heard.

There may be an element of doubt when a speaker is selected from a directory. A company, however, is judged by the competence of its personnel, and it is extremely doubtful if any company would permit uninformed or incompetent personnel to be listed. A speaker naturally is expected to be able to express himself, and thus the important factor becomes the subject. This is a field in which a speakers' directory is invaluable. There is a wide choice of subjects and the treatment may be judged, in many cases, by the description of the talk.

This system of education by means of speakers is admirable as far as it goes. The fact remains, however, that the knowledge is being confined to a relatively small group—a group already convinced of the advantages of welding and hungry for more technical know-how. The people the welding industry have to convince are those to whom welding has but one vague interpretation, "to join together." These people, the general public, are told of every important weld failure. They are not told of the successes. Accidents are newsworthy—satisfactory construction is not.

The AWS, through its sections, has the opportunity not only of reassuring the public but also of popularizing welding.

The Speakers' Directory can play its part in this project by listing informational speakers as well as technical speakers.

Informational Speakers

A technical speaker, in his anxiety to avoid optimistic exaggeration, is sometimes guilty of going to the other extreme and stressing weld failures, flaws, faults and rejects. This is probably on the premise that good welds look after themselves. There is danger, however, in this overemphasis of weld failures. A remark made by a speaker at a technical meeting was an indication of how he could be influenced by conditions. In the course of his talk he said, ". . .It was most refreshing to visit the plant and see perfect welds being produced. In my lab I have got so used to seeing nothing but failures that I had almost forgotten perfect welds existed." This, of course, was an exaggeration on the part of the speaker, but it does reveal a possible attitude of mind brought about by overemphasis. It also shows how easily the uninformed could be influenced against welding as a joining method.

In every city, town and village are luncheon clubs, fraternal organizations and civic groups which can never obtain as many speakers as they need. This is a golden opportunity for the welding industry to provide speakers to tell a cross section of the most influential people in each community the true story of welding.

Many companies have agreed to cooperate in this worth-while project. They have included names of speakers and the subjects upon which they will speak. The approach is nontechnical and can be slanted in any direction. The theme of all talks, to such general groups, should perhaps indicate the gigantic part welding is playing in the American way of life.

Section Activities

If this project to make the public aware of the possibilities of welding is to be a success, it will need the wholehearted cooperation of every section. A nation-wide coverage can be obtained through the medium of the 81 AWS sections. Everyone in the welding industry will benefit by the introduction of the science of welding and its undoubted advantages to the very people who some day may be specifying its use.

Some sections have already telephoned headquarters offering their cooperation and making suggestions. The experiences of each section in the launching of this program will be invaluable to others. The Secretary, Educational Activities Committee, 33 W. 39th Street, New York 18, New York, will act as a clearing house. Send him your views. Tell him of your experiences with this project. The more information you give him the more information he can give to other sections.

The accumulated experience of 13,000 members is valuable only if it is recorded and used to guide others.

EMPLOYMENT SERVICE BULLETIN

Services Available

A-701. Welding Engineer. P. Eng. Age 37; 13 years' experience, including development and application of new methods and procedures of the different phases of welding, brazing, soldering and metallizing. At present chief engineer, with a major North American manufacturing company. Fluent in several languages. Interested in foreign assignment as technical manager or consultant in the welding field.

Positions Vacant

V-352. Metallurgical Engineers with B.S. in metallurgical engineering or metallurgy. Two to five years' experience in metallurgical laboratory of a manufacturing plant desirable. Brazing and welding experience desirable. Assist with development of high-temperature heat exchangers, including new brazing alloys; high-temperature materials; welding and brazing techniques. Plant liaison from pilot operations to production stage. Specification for materials and processes. Possible salary $8000 per year.

V-353. Metallurgical Engineer interested in electrode coating formulation. Leading manufacturer of welding electrodes is expanding its Research and Development Departments. Interesting position available. Excellent facilities, stimulating and congenial atmosphere; fine opportunity for right person. He should take an intense interest in his work and be able to get along with people. Our employees know of this ad.

V-354. Metallurgical engineer. Stable medium-sized company technical group engaged in arc welding research and development offers unusual opportunity for able young metallurgical or chemical engineer to establish himself in good field of specialization which draws on basic sciences and promotes technical growth. Please give age, education, experience and salary expected.

Positions Open—Government. Metallurgists, Metallurgical Engineers and Welding Engineers: in the Metals Joining Branch of the Watertown Arsenal Laboratories for research on (1) problems associated with weld fabrication of missiles, (2) the effects of welding on brittle fracture, and (3) the causes of weld cracking in alloy steel and titanium, etc. Per annum starting salaries of $4480 (B.S. degree), $5335 (M.S. degree) and $7465 (Ph.D.). With qualifying experience, starting salaries may be as high as $8654. Opportunity for part-time graduate study at well-known nearby (Cambridge or Boston) educational institutions is an important added feature; up to six hours per week of regular working hours can be approved for graduate work. Submit Standard Form 57, obtainable from first class post offices, to: Local Civil Service Board (Attention: Miss Niss), Watertown Arsenal, Watertown 72, Massachusetts.

Product Manager—Welding Machines. Man experienced in sales of welding machines required by Metal & Thermit Corp. to supervise and assist nationwide sales organization in promoting entirely new line of machines. Must have administrative ability, marketing experience, knowledge of sales promotion and be willing to travel. Attractive salary plus generous company benefits. Write, outlining previous experience and salary requirements. All replies held confidential. Send replies to: Employee Relations Department, Metal & Thermit Corp., Rahway, N. J.

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Section News and Events

as reported to Catherine O'Leary

POWER SOURCES FOR ARC WELDING

Birmingham, Ala.—The speaker for the January dinner meeting of the *Birmingham* Section held on January 14th at Gulas Restaurant was H. J. Bischel, engineering manager of the Arc Welding Department, Westinghouse Electric Corp., Buffalo, N. Y.

An audience of 65 members and guests heard Mr. Bischel's illustrated talk on "Power Sources for Arc Welding."

His talk covered the development of arc-welding power sources from the original crude methods to the latest developed machines. Particular emphasis was placed on the development and versatility of the new silicon diodes now used in rectifier type machines.

LECTURE SERIES

Cambridge, Mass.—A series of six lectures, a continuation of the previous year's lecture course by the *Boston* Section, will start on March 4th for six consecutive Tuesdays through April 8th, and will be held at Massachusetts Institute of Technology. This year's lecture on weld design will be given by Dr. Harry Udin and guest speakers. The text used will be the *Procedure Handbook of Arc Welding Design and Practice*. A three dollar registration fee will be charged.

STAINLESS-STEEL WELDING

Bridgeport, Conn.—Benjamin F. Doty of the Crucible Steel Company of America was the speaker at the January 16th dinner meeting of the *Bridgeport* Section held at the Fairway Restaurant. Mr. Doty spoke very eloquently on the arts and sciences of welding stainless steel. He gave an excellent portrayal of the problems and answers to many difficulties encountered in the field of welding various types of stainless steels. His talk was supplemented by Jack Goodford, also of Crucible. There was a general discussion with everyone participating. This was an excellent program.

SECTION MEETING CALENDAR

APRIL 4

PHILADELPHIA Section. Engineers Club, Philadelphia, Pa. 7:45 P.M. Panel Discussion: "Welding of Low-Chrome Alloy Steels."

APRIL 7

LEHIGH VALLEY Section. Plant visit.

APRIL 8

NEW YORK Section. Victor's Restaurant, 1 E. 35th St., New York City. Get-together 5:30 P.M. Dinner 6:00 P.M. Program 7:00 P.M. "Arc-Welding Electrodes," D. C. Smith, Harnischfeger Corp.

WESTERN MASSACHUSETTS Section. Blake's Restaurant, Springfield, Mass. Dinner 6:30 P.M. Meeting 7:30 P.M. "Silver-Alloy Brazing," A. W. Swift, Handy and Harman.

APRIL 9

CLEVELAND Section. Manger Hotel, Cleveland, Ohio. Social hour 6:00 P.M. Dinner 6:30 P.M. Meeting 8:00 P.M. "Efficient Use of Steel," Omer Blodgett, The Lincoln Electric Co.

STARK CENTRAL Section. Elks Club, New Philadelphia, Ohio. "Which Welding Process—and Why," O. T. Barnett, Armour Research Foundation.

APRIL 10

KANSAS CITY Section. "Pipe Welding," "Shorty" Cunningham, Northern Natural Gas.

SAGINAW VALLEY Section. Saginaw, Mich. "Resistance Welding Controls."

APRIL 11

DETROIT Section. Engineering Society of Detroit. Dinner 6:15 P.M. Technical Meeting 8:00 P.M. Annual Intersectional "Quiz the Experts" Program.

NORTH CENTRAL OHIO Section. Joint meeting with Columbus Section.

APRIL 14

NORTHWEST Section. Elks Club, Minneapolis, Minn. Happy Half Hour 6:00 to 6:30 P.M. Dinner 6:30 P.M. Panel Discussion: "Welding Education in Twin City Schools."

APRIL 15

HARTFORD Section. Plant tour and joint meeting with Bridgeport Section. Hamilton Standard Div., United Aircraft Corp., Windsor Locks, Conn.

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. "Why So Many Electrodes?"

TOLEDO Section. Maumee River Yacht Club, Toledo, Ohio. Dinner 6:30 P.M. Meeting 9:00 P.M. "Welding for Code Work."

APRIL 16

PROVIDENCE Section. Johnson's Hummocks, Providence, R. I. Dinner 6:15 P.M. "Automatic and Semiautomatic Welding," A. K. Pandjiris, Pandjiris Weldment Co.

APRIL 17

IOWA Section. Plant tour of the Maytag Co., Newton.

MICHIANA Section. South Bend, Ind.

APRIL 18

MILWAUKEE Section. Ambassador Hotel, Milwaukee, Wis. 6:30 P.M. "Methods Engineering as Applied to Welding," Don Cox, Caterpillar Tractor Co.

APRIL 21

PHILADELPHIA Section. Engineers Club, Philadelphia, Pa. 8:00 P.M.

APRIL 24

NIAGARA FRONTIER Section. Continental Inn, Delaware Ave., Kenmore, N. Y. Dinner 6:45 P.M. Meeting 8:15 P.M. "Machine Welding Tools," John Berryman, Air Reduction Sales.

APRIL 25

INDIANA Section. Technical Session and Dinner. 6:30 P.M. "Nondestructive Testing of Welds," Wm. Alaerson, Allison Div., GMC.

PITTSBURGH Section. Georgian Room, Hotel Webster Hall, Pittsburgh, Pa. 7:00 P.M. Twenty-first Annual Tri-State Ladies' Night and Dinner.

Editor's Note: Notices for June 1958 meetings must reach Journal office prior to April 1, so that they may be published in May Calendar. Give full information, concerning time, place, topic and speaker for each meeting.

CHICAGO SPEAKER

Roy B. McCauley was the principal speaker at the January 17 meeting of the Chicago Section. Prof. McCauley's subject was "Elements of Welding Engineering"

CHRISTMAS PARTY

Chicago, Ill.—A majority of the active membership of the *Chicago* Section and their wives attended a Christmas Party held on December 6th at the Club "New Martinique" on Chicago's south side.

Cocktails, dinner, door prizes, dancing and good fellowship was the evening's theme. It was the general opinion of those present that this was the outstanding event of the year.

WELDING ENGINEERING ELEMENTS

Chicago Ill.—Over 100 members and guests attended the January 17th meeting and group dinner of the *Chicago* Section held at Milner's Restaurant in Chicago's downtown area.

The premeeting movie entitled "Eye to the Unknown" dealt with the science of spectrometry and its application to our various oil and gas industries and TV tube manufacturers.

Technical speaker for the evening was Prof. R. B. McCauley [M62], of Ohio State University. His subject, "Elements of Welding Engineering," covered the basic requirements for persons aspiring to become welding engineers and was accompanied by color slides taken on the campus of Ohio State. The slides portrayed various welding and testing scenes, as well as other classroom scenes which are a daily occurrence at the university.

RAILROAD CARS

Cincinnati, Ohio.—The *Cincinnati* Section had its largest attendance this year at its dinner meeting at the Hartwell Country Club on January 28th, with 75 members. An excellent cocktail hour, prior to the dinner, put everyone in good spirits. William Schuster [M62], of ACF Industries, presented an excellent talk on "Welding of Railroad Cars," which covered the welding of freight cars. The presentation was accompanied by a series of slides showing the various methods and techniques used for the welding of heavy sheet. He showed arrangements on double and triple head automatic setups, and the considerable increase in the use of automatic welding in the heavy equipment field. The concluding remarks consisted of a motion picture showing the complete sequence in the welding of a freight car. The speaker also gave an excellent comparison on the cost per pound of deposited metal by a number of different methods of welding.

WELDING CONFERENCE

Cincinnati, Ohio.—On March 20, 1958, the *Cincinnati* Section will sponsor the second annual welding conference. This year, a one-day technical meeting will be held.

Tentative plans include a morning and afternoon session on brazing, metal-arc welding, metallurgy, resistance welding and questions and answers. A social hour and banquet in the early evening, featured by a prominent guest speaker, is included in the five dollar registration fee.

ANNUAL EXECUTIVES' NIGHT

Cleveland, Ohio.—The meeting of the *Cleveland* Section held on January 8th, was the annual executives' night dinner meeting. Approximately 400 members and their guests met in the ballroom of the Hotel Manger for dinner, followed by an outstanding talk by Dr. Jason J. Nassau, head of the Astronomy Department of Case Institute of Technology and Director of the Warner and Swasey Observatory in Cleveland. His subject was "Satellites and the International Geophysical Year."

The dinner was preceded by a social hour and later followed by a short business meeting. The business meeting consisted chiefly of the presentation of a scroll honoring Arthur Portz, past chairman, for his long and effective service with the Cleveland Section. The scroll was presented on behalf of the entire section membership by Chairman William P. Mayor.

SATELLITES DISCUSSED AT CLEVELAND MEETING

Dr. Jason Nassau, center, spoke on satellites and the International Geophysical Year at the January 8th meeting of the Cleveland Section. Second Vice-Chairman Tom Dempsey is at left and Chairman Bill Mayor is at right

Also at the speaker's table are *(left to right)*: L. S. Cawrse, president of Consolidated Iron and Steel Mfg. Co.; 1st Vice-Chairman Harry E. McBride and Sec.-Treas. Ray Metzger, Jr.

At this, the Annual Executives Night dinner meeting, Past-Chairman Art Portz was presented with a scroll honoring his service to the Cleveland Section

Dr. Nassau, a native of Smyrna, Asia Minor, and a graduate of Syracuse University, is one of the country's leading astronomers, and has received recognition at astronomical meetings throughout the world. He was one of two Americans attending the dedication of the Pulkovo Observatory in Leningrad, Russia. His opening comments reflected his concern for the apparent educational lead of Russia and thought it significant that the Sputniks had awakened America from its "intellectual lethargy" and have made us realize "the intellect is vital in preserving our freedom and way of life." He pointed out how the Russians pay attention to their gifted children, seeing that they are educated. He commented how they were taught English and encouraged to read our technical literature, while we are unable to read Russian journals. The Russian school year, he noted, is based on a 5½ day week and lasts ten months.

He observed that Oct. 4, 1957, would go down in history as a date as significant as Columbus discovering the new world. He was enthusiastic in predicting travel to the moon in the next ten years and distant space travel within the confines of this century. Much would be learned, he stated, during the International Geophysical Year now in progress, but that it would take many years to digest all of the knowledge gathered. He showed a number of interesting slides describing how satellites are launched.

WELDED STRUCTURES

Denver, Colo.—The *Colorado* Section held a regular meeting on Jan. 14, 1958 at the El Rio Grande Cafe in Denver. The group enjoyed a social hour before dinner. After dinner they were privileged to hear a talk by one of their own members, Paul J. Foehl, chief engineer of the Midwest Steel and Iron Works of Denver. The subject of his talk was "Welding—Its Application in Structural Steel Fabrication." He demonstrated a broad knowledge of the subject. In the course of his talk, Mr. Foehl touched on design for welding, methods of minimizing warpage in fabrication and erection, and discussed the relative merits of riveting, high-strength bolting, mild-steel bolting and welding.

JOINING ALUMINUM

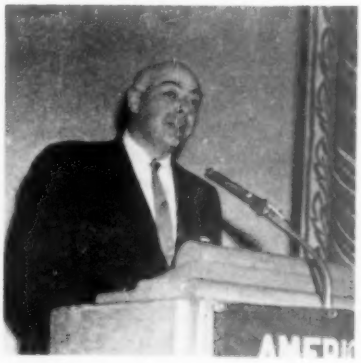
Dayton, Ohio.—Forty-eight members and guests attended the meeting of the *Dayton* Section held on January 14th at the Dayton Engineers Club.

Interesting color films on salmon and sea-bass fishing, along with a film on hunting of brown bear, were shown.

The technical speaker, Lloyd A. Cook [M], president of Ravens Metal Products Inc., gave a very interesting talk on "Joining Aluminum to Other Metals." He described a successful method of joining aluminum conductor bars to copper bars by silver brazing the surface of the copper bar followed by arc welding

PAST-CHAIRMEN HONORED BY DETROIT SECTION

Among those present at the Past-Chairmen's Night held by the Detroit Section on January 10th were *(left to right)*: Al Last, Tom Crawford, Ed Brown, Jim Rainey and Jim Johnson



Technical speaker was William J. Farrell. His topic was the resistance welding of heavy structures

Also enjoying the dinner and the conversation are *(left to right)*: Roy Clark, Bill Smith, Al Lewis, Keith Sheren and Don Corey

Al Hackett, who spoke on the early days of welding, receiving a gift from Section Chairman Gordon Kirkwood

HOUSTON SECTION HEARS TALK ON SUBMERGED-ARC WELDING PROCESS

Shown above is part of the large group that attended the January 22nd meeting of the Houston Section to hear Mr. Silvers

Flanked on the left by Hubert Crick, Section vice-chairman, on the right by Chairman Roy Pringle, is guest speaker Floyd L. Silvers. He spoke on "Experimenting with Submerged-Arc Welding"

of the two bars employing an aluminum filler metal.

He also described research in "cold welding" of heavy aluminum and copper sections and aluminum and magnesium sections. The talk was illustrated with color slides and sample test sections.

PAST-CHAIRMEN'S NIGHT

Detroit, Mich.—At its regular meeting on January 10th, the *Detroit* Section honored its past chairmen, and many turned out for this occasion.

Al Hackett, the coffee speaker, gave a very interesting talk on the early days of welding. He is well qualified to speak on this subject, as he is one of those who have helped the industry grow from infancy. He is associated with Progressive Welder Sales Co. Approximately 80 guests attended the dinner.

The regular meeting in the ESD Auditorium was addressed by Wm. J. Farrell, chief application engineer, Sciaky Bros., Inc., Chicago. Mr. Farrell presented an excellent paper on heavy resistance welding, as performed in France. He used appropriate slides to show methods of welding heavy I beams, building trusses, etc., with giant gun and spot welders. The welding of freight cars and passenger coaches was also shown, proving once again the vast progress that the welding industry has made in the various types of welding processes and methods during the past fifty years.

PLANT VISIT

Wixom, Mich.—A special technical meeting of the *Detroit* Section was held on January 23rd, when the Lincoln Division of the Ford Motor Co. was host to 250 members and their guests for a visit to their new assembly plant at Wixom, to see the latest methods of resistance welding as applied to the new Lincoln cars. Some of the features noted included the strict adherence to AWS Standards as to nugget size, pull tests and penetration of welds. The welding certification program features periodic checks with a Brush recording weld analyzer to determine the constancy of weld cycles, pressure and current used, in order to keep the high standard of welding required by the specification of this quality car accented by the development of "unitized construction." The underbody and body are welded together, thus eliminating the use of a separate frame. From all reports, those who attended were quite impressed with what they had seen.

SUBMERGED-ARC WELDING

Houston, Tex.—The *Houston* Section held its monthly meeting on January 22nd at the Ben Milam Hotel.

Guest speaker was Floyd L. Silvers [AWS], welding supervisor, National Tank Co., Tulsa, Okla. His subject was "Experimenting with Submerged-Arc Welding."

Mr. Silvers set forth a number of practical requirements which are needed for proper control of good automatic welding. Among them were joint design, speed, tabs, procedure and control, good ground connections, clean flux and good fit-up.

To illustrate the effect of certain factors influencing automatic welding, a large number of colored slides was shown. Such variables as the amperes, volts, speed and off-center distance were used to show the change on the weld bead. The weld bead width, height above plate and depth of penetration were measured. The cross sections of the beads, together with the measurements, effectively illustrated that changes would be brought about if the foregoing variables were not held under proper control.

AUTOMATIC WELDING

Beaumont, Tex.—The *Sabine Division* of the *Houston* Section held a dinner meeting on January 23rd at the Flying Chef Cafe at Jefferson County Airport. "Design for and Applications of Automatic Welding" was the subject covered by speaker R. A. Wilson [AWS], chief of application engineering, Lincoln Electric Co., Cleveland, Ohio.

Mr. Wilson presented a very interesting comparison on hand welding, semiautomatic, fully automatic, twin-arc, tandem-arc and triple-arc welding showing currents used and speeds of travel for each of the butt, fillet and groove welds. He recommended the different types of joints for semi- and full-automatic welding and stressed the importance of cleaning plates before welding. He showed slides of the research being done on the "three o'clock" welding of longitudinal seams on large diameter pipe.

The effects of different voltage and current settings were demonstrated by free-hand sketches on the blackboard. Also the proper location of each pass in the welding groove was demonstrated by cross-sectional sketches of the joints. He discussed the practice of adding alloy elements to the flux mixture on submerged weld-

ROCKETRY PANEL HOLDS GROUP DISCUSSION NIGHT

Panel of five experts in welding and brazing participated in "Group Discussion Night" sponsored by the Aircraft and Rocketry Panel of the Los Angeles Section on January 9th. Seated *(left to right)* are: Alfred Brothers, William Perrins, George Prescott, Salvatore Robelotto and Carl Muser. Charles B. Smith, who acted as moderator, is shown standing at right

ing for special applications.

CONSTANT-VOLTAGE WELDING

Des Moines, Iowa.—The regular monthly meeting of the *Iowa* Section was held in the Garden Room of the Kirkwood Hotel on January 16th with an attendance of 52 members and guests at the dinner and meeting.

Speaker was John Headapohl [AWS], manager of the Automatic Welding Department of Hobart Brothers, Troy, Ohio. His topic, "Constant Voltage—A Simplified Welding Tool," was accompanied by slides. He did an outstanding job explaining the theory and application of constant-voltage welding. He mentioned that this type of welding equipment has good arc-starting characteristics and are stability. He stated that with constant voltage, automatic welding equipment, the amperes are controlled by the amount of wire consumed. His subject was very interesting.

LONG BEACH SECTION HEARS NATIONAL OFFICERS

The January 17th meeting of the Long Beach Section was highlighted by talks by President C. P. Sander and National Secretary Fred Plummer. Pictured above are *(left to right)*: J. S. McClure, Mr. Plummer, Ray Davenport, Mr. Sander, C. L. Breese and Frank Pope

A number of the members and guests who were on hand to hear Mr. Plummer speak on "Welding Achieves New Firsts" and Mr. Sander on Society activities

CONDUCTED TOUR

Kansas City, Mo.—The regular monthly meeting of the *Kansas City* Section was held on January 16th. After a social hour beginning at 5:30 P.M., a group of 85 members and guests enjoyed a steak dinner at the Golden Ox Restaurant.

A brief business meeting followed, at which time it was announced that the executive committee had decided to sponsor a 10-week welding course at Kansas City University beginning February 18th. The instruction is for those interested in learning the fundamental principles of welding and will last for two hours each evening.

The meeting was then adjourned and the group traveled by bus to the TWA Overhaul Base in Platte County for a conducted tour through the new engine overhaul building and the huge hangars that can accommodate 5 Super G Constellations side by side at the same time. All agreed that this was an outstanding experience.

PAST-CHAIRMEN'S NIGHT

Allentown, Pa.—The January meeting of the *Lehigh Valley* Section held on January 6th, was Past-Chairman's Night and nine of the thirteen past chairmen were in attendance. Past-Chairman C. L. Kreidler gave a history of the Section and introduced the past-chairmen who were present.

In lieu of the usual technical meeting, a "Battle of the Cities" was staged with Dr. Robert D. Stout as moderator and A. T. Bavaria, M. F. Couch and F. K. Mack as judges. Members and guests from the areas of Allentown, Bethlehem and Easton comprised the teams. Questions on technical aspects of welding, operating procedures, welding symbols and weld inspection were answered by each of the teams. The Bethlehem team, scoring the most points, was judged the winners.

After the quiz program, a get-together, featured by coffee and doughnuts, gave the losers an opportunity to alibi their wrong answers.

WELDING PROGRESS

Long Beach, Calif.—The regular

NATIONAL LEADERS MEET WITH LOS ANGELES SECTION OFFICERS

Plans for the AWS 1960 Welding Show in Los Angeles were discussed at a luncheon meeting sponsored by the officers of the local Section. Left to right are National Membership Chairman Chas. Smith, President "Sandy" Sander, Secretary Fred Plummer, 10th District Director Francis V. McGinley and National Exposition Manager Robert T. Kenworthy

Also discussing the responsibilities of the Los Angeles Section for the 1960 Welding Show are Section Chairman Dave O'Connor, Mr. Plummer, Section Secretary Dick Hayes and Section Vice-Chairman John Ross

monthly dinner meeting of the *Long Beach* Section was held at Eaton Chicken House on January 17th. Honored guests were President C. P. Sander, who gave a short summary of past and present activities of the SOCIETY, and Secretary Fred L. Plummer, the technical speaker.

Mr. Plummer's presentation, "Welding Achieves New Firsts," was supported by a series of 35-mm slides which gave a very graphic story. This was something different and held the attention of everyone. Mr. Plummer was highly complimented on his talk.

LOS ANGELES SECTION PLAYS HOST TO SANDER AND PLUMMER

Dave O'Connor, Section chairman, opens January 16th meeting which featured President "Sandy" Sander and Secretary Fred Plummer as guests

President Sander speaks on Society staff and activities before AWS members and guests

Secretary Plummer presenting his semi-technical talk on "Welding Presents New Firsts"

Proudly displaying their 25-year plaques are *(left to right)*: Clayton, Allen, P. D. McElfish and Hugo Hiemke

GROUP DISCUSSION

Huntington Park, Calif.—Approximately 125 members and guests of the *Los Angeles* Section *Aircraft and Rocketry Panel* convened at the Elks Lodge in Huntington Park on Thursday, January 9th, to enjoy cocktails, dinner and a group discussion on important phases of welding. The program for the evening was initiated by the Aircraft and Rocketry Panel for the purpose of creating a greater interest in meeting attendance and proved to be quite a success.

C. B. Smith, past chairman, moderated the panel discussion covering five areas in the welding field currently of interest to the aircraft and missile industry.

Five invited guests attended the meeting to open discussion on each area. The guests, each a specialist in a particular phase of welding, were Carl Muser of North American Aviation, Salvatore Robelotto AWS, of Convair, George Prescott of C. F. Braun Co., Bill Perrins of Southwestern Engineering Co. and Al Brothers of the Jet Propulsion Lab at Cal Tech.

The discussion covered the following subjects:

1. Vacuum and controlled-atmosphere brazing.
2. Brazing alloys for honeycomb structures.

3. High - current - density short-time-cycle resistance welding.
4. Resistance-welded honeycomb sandwich.
5. Welded thin-wall pressure vessels.
6. New arc-welding processes.
7. Weldability of high-strength titanium alloys.

All the above were discussed in a semitechnical manner so that they could be well understood by the average welder.

The program proved to be something different and one of interest to all.

1960 WELDING SHOW

Los Angeles, Calif.—The *Los Angeles* Section was honored by the presence of several national officers at an informal luncheon held on January 16th in the Trojan Room of the Biltmore Hotel. The officers present were President C. P. Sander, National Secretary F. L. Plummer, National Exposition Manager R. T. Kenworthy and National Membership Chairman C. B. Smith. Also present, and prominent in SOCIETY affairs, was Past-Chairman F. V. McGinley.

The luncheon was held for the purpose of discussing the welding show to be held in Los Angeles in 1960, and other topics of similar importance.

The national officers were hosted by the following Section officers and Executive Committee: Chairman Dave O'Connor, First Vice-Chairman John Ross, Secretary-Treasurer Dick Hayes, Membership Chairman George Murphy, Aircraft and Rocketry Panel Chairman Leo West, Panel Secretary Bruce Baird, Recording Secretary Al Thompson, Ways and Means Chairman Charles Concannon, By-laws and Codes Chairman Herb Evans, Entertainment Chairman John Wyley and Past Section Chairman Ed Williams.

WELDING PROGRESS

Huntington Park, Calif.—The *Los Angeles* Section was honored to have as guest speakers, at their January meeting, two prominent national officers, President C. P. Sander who spoke on the SOCIETY's staff and activities, and Secretary Fred L. Plummer who presented a semitechnical talk on "Welding Achieves New Firsts."

The dinner meeting was held at the Elks Lodge in Huntington Park on Thursday, January 16th.

Before his association with the SOCIETY as secretary, Mr. Plummer was welding engineer on many important bridge, building, dam and foundation projects and was chief design engineer for the Main Avenue Bridges. These include the first all-welded bridges constructed in the Cleveland area. In the course of presenting his paper, Mr. Plummer discussed the many outstanding welding applications, including buildings, bridges, storage vessels, piping, heavy equipment, aircraft, ships, etc., covering also the many welding processes and materials. His presentation was well supported with slides of various welded structures in various parts of the world.

In concluding the evening's program, the Section's Vice-Chairman, John Ross, honored the following "old timers" by presenting them with 25-year plaques: Hugo Hiemke, president, California Alloy Products Co., Los Angeles, Calif.; P. D. McElfish, vice-president, Perry Kilsby, Inc., Los Angeles, and past-chairman AWS Los Angeles Section; Clayton "Moe" Allen, general plant superintendent, Los Angeles Bureau of Water and Power; and Turner Smith (not present), previously with General Petroleum Co. and now retired.

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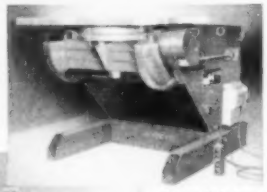

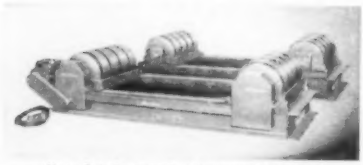

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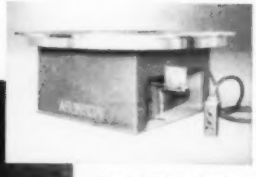

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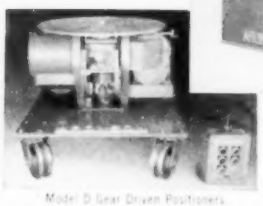

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HIGH-TEMPERATURE MATERIALS DISCUSSED BEFORE NEW JERSEY SECTION

Premeeting dinner being enjoyed by the members of the New Jersey Section on December 17th. Meeting was held at the Essex House in Newark, N.J. with thirty-seven members and guests present

Speaker R. C. Kopituk discussing the selection and fabrication of high-temperature materials

SAFETY IN WELDING

Madison, Wis.—The *Madison* Section met on January 16th at the Eagle's Club. Featured speaker was Edward Otterson, industrial engineer for the Hygiene Division, Wisconsin State Board of Health at Madison, Wis.

Safety in welding practices was the topic of Mr. Otterson's speech. He covered the inert-gas welding processes and their hazards. His very excellent talk was illustrated with slides and tape recording.

Mr. Otterson explained the hazards and problems of ozone which is found in the inert-gas welding processes.

Mr. Otterson's talk was very well received by the members of the Madison Section. After the question-and-answer period, a light buffet lunch with coffee was served.

RESISTANCE WELDING

Baltimore, Md.—On the evening of January 17th, 25 members and friends of the *Maryland* Section gathered at the Baltimore Engineers Club for dinner and listened to a very informative and vital talk on the various factors to be considered in connection with Civil Defense. The talk was presented by Gerald Peer of the Volunteer Speakers Bureau, Civil Defense Agency. A 16-mm sound film was presented showing the effects of atomic and hydrogen bombings.

Approximately 45 persons were present for the technical talk given by F. R. Woodward of the Taylor Winfield Corp. on the topic "Resistance-Welding Machine Development and Applications." Mr. Woodward briefly reviewed resistance-welding processes and then described and commented on the many resistance-welding applications.

The March 21st meeting on "High-Current-Density Inert-Arc Welding" will be addressed by J. E. Dato AWS, of the Linde Co.

LADIES' NIGHT

South Bend, Ind.—The most successful Ladies' Night program ever sponsored by the *Michiana* Section took place on January 16th when 58 members and guests came out to hear Al Rerick of the Studebaker-Packard Corp. describe a trip he and Mrs. Rerick had taken to Egypt.

Amply illustrated by color slides, Mr. Rerick's near-professional job of guiding the audience through the land of "Sand, Pyramids and Tombs" provided a most entertaining program for both members and their feminine companions. A social half-hour preceded the dinner.

WELDING PROCESSES

Milwaukee, Wis.—The regular monthly dinner meeting of the *Milwaukee* Section was held on January 17th at the Ambassador Hotel with 105 members and guests in attendance.

After a fine smorgasbord dinner, George Spiedel, director of the Washington Park Zoo, took the audience on a "verbal tour" of the new zoo now under construction.

The technical presentation was covered by John Mikulak AWS, assistant to the vice-president in charge of manufacturing, Worthington Corp. Mr. Mikulak spoke on "Practical Aspects of Various Welding Processes." His talk included manual arc welding, inert-gas tungsten-arc and metal-arc welding and submerged-arc welding both semiautomatic and automatic. His talk was accompanied by many excellent slides showing the various processes. Mr. Mikulak stated the breakoff between manual and semiautomatic welding depends a lot on the attitude of management. Proper design for each process is also a factor. His talk was well received.

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During the month of January, the Milwaukee Section held its annual educational program. The theme of this year's program was "Automatic and Semiautomatic Welding Processes." Three lectures held at the Marquette University Science Building were well attended.

On January 6th, R. A. Wilson AWS, the Lincoln Electric Co., discussed semiautomatic submerged arc and various automatic processes.

On January 13th, E. J. Egan AWS, Caterpillar Tractor Co., discussed high-pressure cylinder welding using the full automatic process and twin-arc welding of road equipment. L. Nielsen AWS, Caterpillar Tractor Co., discussed data, applications and procedures of the magnetic-flux shielded-arc welding process.

On January 20th, J. A. Howery AWS, National Cylinder Gas Co., discussed data, applications and procedures of the CO_2-shielded flux-cored electrode welding process. R. J. Keller AWS, A. O. Smith Corp., discussed data, applications and procedures of the CO_2-shielded metal-arc welding process.

A plant tour of the Falk Corp. on January 27th closed a very successful educational program.

HIGH-TEMPERATURE MATERIALS

Newark, N. J.—On Dec. 17, 1957, the *New Jersey* Section held its regular monthly dinner meeting at the Essex House, in Newark.

Thirty-seven members and guests enjoyed an excellent dinner, followed by the showing of a film in color entitled "Notre Dame Victory to Cliffs Victory" describing the conversion of war built Victory Ship into a Great Lakes ore carrier and follow-

ing the delivery of the carrier from the shipyard in Baltimore, Md., up the Mississippi River through Chicago to Lake Michigan.

Fifty - six members and guests listened with interest to Raymond C. Kopituk, the speaker for the evening, who chose as his subject "The Selection and Fabrication of High-Temperature Materials in the Range of Over 1700° F."

Mr. Kopituk is at present manager of materials at Reaction Motors, Inc. He received his B.S. degree in Metallurgy from Notre Dame in 1945 and is a member of the Rocket Society for Metals and Aeronautical Material Specifications Committee for SAE. His talk, illustrated with slides, described the problems of materials encountered in rocket motors caused by the high temperatures and corrosive fuels used in the combustion chambers, showing the method of fabrication by welding of the injector head, combustion and thrust chamber and cooling jackets.

There was the usual after meeting social get-together with refreshments.

SPOT WELDING ALUMINUM

New York, N. Y.—The first meeting of the new year of the *New York* Section was held on Jan. 14, 1958.

J. W. Kehoe [AM], was the speaker of the evening. Mr. Kehoe is manager of the Headquarters Manufacturing Metals Joining Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa., and the topic selected was "Spot Welding Aluminum with Single-Phase Equipment."

The program proved to be a very interesting one as the speaker, who has had considerable experience with the subject, gave the audience a clear picture of spot welding with single-phase equipment as well as the use of "three-phase equipment." Mr. Kehoe informed the audience that a schedule had been developed for spot welding widely used aluminum alloys in 257 different combinations with only eight closely related welding-machine settings. He explained that the increased use of aluminum products is due to the economic advantages as the volume by weight is considerably more than copper or steel and, hence, lower freight charges per pound of material; its light weight is desirable on aircraft apparatus, and it is reasonable in price. In addition, aluminum has nonmagnetic properties and has good weldability, particularly with the inert-arc process using consumable and nonconsumable electrodes.

The lecture resulted in a considerable discussion because of numerous questions from the audience.

The meeting was attended by 45 engineers and welders, a good turnout in spite of the adverse weather conditions at the time.

The meeting has held at 1 E. 35th St., New York City, where an excellent dinner was served prior to the meeting.

WELDING HIGH ALLOYS

Oak Ridge, Tenn.—The *Northeast Tennessee* Section held its January technical meeting at the Elks Club in Oak Ridge, Tenn., on the evening of Jan. 20, 1958. A delicious ham dinner was served to the assembled members and guests.

The subject of discussion for the technical portion of the meeting was "Welding of Nickel- and Cobalt-Base Wrought Alloys." A fine presentation was given on this subject by R. D. Culbertson [AM], assistant director of Development and Technical Services for the Haynes Stellite Co. The talk was accompanied by slides dealing primarily with the metallurgical properties of the alloys under discussion. A lively question-and-answer period followed the talk.

Plans are now firm for the Spring Educational Series sponsored by the Northeast Tennessee Section. The series is to be held at the University of Tennessee on Mar. 11, 18 and 25, 1958. The three lectures are to be on "Recent Development in Cutting and Brazing."

WELDING STAINLESS STEELS

Olean, N. Y.—The *Olean-Bradford* Section met on January 21st for dinner and meeting at the Castle Restaurant in Olean, N. Y. A most interesting talk on welding stainless steels was given by David W. McDowell, Jr. [AM], of the International Nickel Co.

Members from Bradford, Pa., Lewis Run, Pa., and Olean, N. Y., turned out for the meeting, despite the bad weather.

LADIES' NIGHT

Peoria, Ill.—A special Ladies' Night Meeting of the *Peoria* Section was held on January 15th at the Mecca Supper Club.

After enjoying a special prime rib dinner, the audience was treated to a demonstration in copper enameling put on by Peter T. McKinney [AM], manager of pipe lines for the Union Carbide Corp. This demonstration was very interesting and Mr. McKinney's talk was quite humorous.

He demonstrated different ways of making designs and colors in copper enameling and explained which equipment would be necessary for this hobby.

All ladies received a pair of ear rings as a gift, and there were three door prizes (ash trays) for the men.

This meeting was enjoyed by both the ladies and the members.

SPEAKS BEFORE PEORIA SECTION

Peter T. McKinney addressed the Peoria Section at the January 15th Ladies' Night Meeting on the art of copper enameling. He is shown here demonstrating the use of an air-acetylene torch for copper enameling

PAST-CHAIRMAN'S NIGHT

Philadelphia, Pa.—Sixteen past chairmen were honored by the *Philadelphia* Section at its regular monthly meeting on January 20th at the Engineers' Club. Other honored guests were Mr. and Mrs. M. E. McPherson and their niece, Miss S. Whittaker. Mrs. (Bernice M.) McPherson is a past chairlady of the Washington (D. C.) Section while Mr. McPherson is a member of the Maryland Section. Approximately 120 members and guests were in attendance.

L. H. Christensen officiated as master of ceremonies for the past-chairmen's program, introducing each one with an interesting anecdote or sketch. Each past-chairman responded with remarks suitable to the occasion. The following were present and were given gold past-chairmen's pins in appreciation of services to the Section: R. D. Thomas, 1927–28; J. J. Dunne, 1929–30; L. H. Christensen, 1931–32; C. I. MacGuffie, 1936; T. M. Jackson, 1937; H. W. Pierce, 1942–43; E. R. McClung, 1947; H. J. Irrgang, 1948; L. D. T. Berg, 1949; O. C. Frederick, 1950; K. Wm. Ostrom, 1951; R. A. Guenzel, 1952; R. D. Bradway, 1953; R. D. Thomas, Jr., 1954; E. E. Goehringer, 1955; and A. M. Garcia, 1956.

LEAD PANEL DISCUSSION IN PHILADELPHIA

Weldability of heat-resisting alloys was the subject of the panel discussion held by the Philadelphia Section on January 3rd. Panel leaders were *(left to right)*: A. J. Ostrosky, H. Kurtz, H. B. Gayley and J. W. Juppenlatz, moderator

Professor Robert D. Stout [AWS], head of the Department of Metallurgy of Lehigh University, spoke on the subject "The Weldability of Carbon and Low-Alloy Steels." Dr. Stout very effectively presented data in answer to the questions: (1) How readily can a sound weldment be produced? (2) Will the properties of the weldment be suitable for the intended service? As the applications for welded steel become more severe, the use of low-alloy, high-strength steels in place of carbon steels has raised these same weldability questions for the new materials. Dr. Stout presented some of the results of work conducted at Lehigh University for the Pressure Vessel Research Committee and the Weldability Committee. Comparative data were presented on the weldability and properties of carbon and high-strength steels. He discussed welding defects; how they occur and how to avoid them. Dr. Stout also very understandably discussed the properties needed in weldments: ductility, fatigue strength, notch toughness, etc.

The January Panel Discussion was held on Friday, the 3rd, at the Engineers' Club. A panel consisting of A. J. Ostrosky, H. Kurtz and H. B. Gayley was ably led by J. W. Juppenlatz. The subject "Weldability of Heat-Resisting Alloys" was very well presented and stimulated an enthusiastic discussion period.

PHILADELPHIA SECTION HONORS PAST CHAIRMEN

These are the past chairmen of the Philadelphia Section who were honored at the January 20th meeting. Front row *(left to right)*: C. I. MacGuffie, E. R. McClung, E. E. Goehringer, L. H. Christensen. *Rear:* A. M. Garcia, R. D. Bradway, T. M. Jackson, O. C. Frederick, R. A Guenzel, R D. Thomas, K. Wm. Ostrom, J. J. Dunne, R. D. Thomas, Jr., H. J. Irrgang, L. D. T. Berg and H. W. Pierce

Seated at the Speakers' table are Carl Schaub, program chairman; Dr. R. D. Stout, guest speaker; and Byron Gates, section chairman. Dr. Stout spoke on Weldability of Steels

Special guests at the meeting were M. E. McPherson, Maryland Section; Miss S. Whittaker and Bernice M. McPherson, past chairlady of Washington Section

SAFETY AND INDUSTRY HYGIENE

Pittsburgh, Pa.—Eighty-eight members and guests of the *Pittsburgh* Section were present on January 15th in the auditorium of the Mellon Institute of Industrial Research to hear two speakers who gave exceptionally good talks covering all phases of safety in welding and cutting both from the standpoint of handling equipment and health considerations. The first speaker was L. G. Matthews [AWS], assistant manager, Safety Codes Department, Linde Co., New York City. The second speaker was S. W. Speicher, administrator, Industrial Hygiene Department, Westinghouse Corp., East Pittsburgh, Pa.

The dinner, which preceded the meeting, was held in the Hunt Room of the Hotel Webster Hall and was attended by 56 members.

STRUCTURAL WELDING

Portland, Ore.—The January dinner meeting of the *Portland* Section was held on January 14th at the Heathman Hotel with 75 members and friends at the dinner.

Featured speaker at the meeting was James F. Lincoln [AWS], chairman of the board, Lincoln Electric Co.

Mr. Lincoln spoke on "Improved Processes in Structural Welding," and presented many thought-provoking ideas to the group which had now grown to over 80. Mr. Lincoln pointed out the fact that although welding can effect a 20% savings of steel on bridges, buildings, etc., we are

too prone to accept present design. We overlook the fact that design is not static; and by holding to outmoded designs produced primarily for riveted structures, we are not taking advantage of the opportunity that welding gives us. Many outmoded building codes and standards are keeping welding from being utilized fully. He also predicted an expanding field for welding in the repair of automobiles, farm equipment and contracting machinery.

At the conclusion of his talk, a brisk question-and-answer period took place. During this it was pointed out that Portland's latest bridge fully utilizes welding.

On January 10th, AWS President C. P. Sander and National Secretary F. L. Plummer were guests of the Officers and Executive Board at a luncheon meeting at the Columbia Edgewater Country Club.

COVERED ELECTRODES

Seattle, Wash.—Something new was tried by the *Puget Sound* Section for the annual Christmas party and, being such a success, it will probably be carried on in years to come. Instead of the usual Christmas party, the membership voted to have a regular meeting with local speakers and to use the money normally spent on the party for a student scholarship in welding. The meeting was a tremendous success, having one of the largest attendances of the entire year.

The local members who supplied the evening's talks were John Bert [illegible], chief welding engineer at the Puget Sound Naval Shipyard, speaking and showing slides and samples on coated-electrode weldments made using a new method of copper backings grooved to insure sound root deposits, and Olaf Tellefsen, representing ASAB of Norway, who showed a film and discussed welding of aluminum superstructures in Norway with coated electrodes.

In addition to the fine program, four honorary memberships were awarded to retired members who had contributed considerably to the Society in their active years. Those receiving the awards were A. G. Bissell, Joe Holt, J. H. Tadlock and Sidney K. Smith. Mr. Bissell has contributed much to welding dating back to 1915 when he wrote one of the first master's theses on arc welding, he was then associated with the Westinghouse welding department, and finally with the Navy Bureau of Ships where he was the principal welding engineer in Washington, D. C.

Mr. Holt has contributed much to welding, dating back to 1938 when he published a treatise on flame straightening titled a "Friend in Need."

Mr. Tadlock, an Oregon State graduate, was sales engineer for General Electric Co. and manager of the Hazeltine Co. and, having been a past chairman and charter member of the Puget Sound Section of AWS, has contributed much to welding.

Mr. Smith, now retired as District supervisor of the American Bureau of Ships, has long been a member of AWS and has contributed much to the growth and advancement of welding in this area.

Everyone in attendance at this meeting seemed to enjoy themselves thoroughly and are in favor of continuing it in years to come.

ULTRASONIC WELDING

Saginaw, Mich.—On Thursday, January 9th, the *Saginaw Valley* Section held its monthly dinner meeting at the Hi-Life Inn, Saginaw, Mich., with 80 members and guests present.

The program presented by John G. Thomas, in charge of the Metallurgical Laboratory of Aeroprojects, Inc., West Chester, Pa., was entitled "Ultrasonic Metal Joining."

Mr. Thomas illustrated his lecture with a very fine series of slides showing the progress of ultrasonic joining of common metals and bimetals as related to minimum required physical strengths. Photomicrographs were used to illustrate the typical type of solid-state fusion common to this relatively new welding process. Details of vibratory frequency, electrical energy requirements and basic types of equipment were also discussed.

The program was very well presented and received considerable compliment.

MAGNETIC-FLUX WELDING

St. Louis, Mo.—The *St. Louis* Section met on Jan. 9, 1958 at Ruggeri's Restaurant with 98 members and guests attending.

Guest speaker for the evening's technical meeting was J. E. (Ed) Dato [illegible], Linde Co., eastern regional manager, Electric Welding, New York, N. Y. Mr. Dato's talk was on "Magnetic-Flux Gas-Shielded Arc Welding of Carbon Steel." Slides were used to support the discussions of the process and the equipment used. A number of applications was also discussed and a sound and color movie was shown so that the process could be seen in action. An informal question-and-answer session ended a very successful and enjoyable evening.

Prior to Mr. Dato's talk, Frank Mooney, assistant secretary, advised the attending members that plans for the Society's forthcoming annual meeting to be held in St. Louis, April 14–18, were progressing without interruption. He outlined the entire

DATO ADDRESSES ST. LOUIS SECTION

Seated at the Speakers' table at the January 9th meeting of the St. Louis Section are George Bland, Harvey Gillerman, F. J. Mooney, AWS assistant secretary; P. C. Enslin, Section chairman; E. G. Mathae, 1st vice-chairman; J. E. Dato, technical speaker; R. A. Near and T. J. Ryan, Section secretary

Mr. Dato shown while presenting his talk on "Manual Magnetic-Flux Shielded-Arc Welding"

week's program and stressed the urgency for the members to offer their services during the week of the meeting. He stated that the manpower requirements for an annual meeting are very heavy and require 100% cooperation of Section members.

WELDED STRUCTURES

South Palo Alto, Calif.—Two national officers were the scheduled speakers at the January meeting of the *Santa Clara Valley* Section held on January 21st at Hal's Restaurant in South Palo Alto.

The speakers were President C. P. Sander, who is general superintendent of the Consolidated Western Steel Division, U. S. Steel Corp., Vernon Plant, and Fred. L. Plummer, national secretary.

Mr. Sander's talk covered the history and organization of the SOCIETY; some notes about the welding shows for the next several years; financial structure of the SOCIETY; and data on the types of personnel in the SOCIETY.

Mr. Plummer had a large number of very interesting slides showing types of welded structures of towers, tanks bridges and buildings; including different materials also. The structures shown are from widely scattered parts of the world which added to the interest. Mr. Plummer also gave an outline of the various technical committees of the Society, including accomplishments to date and standards we are working toward.

WELDING SHOW

San Jose, Calif.—The Second Welding, Brazing and Heat-Treating Show, sponsored by the *Santa Clara Valley* Section, will be held on March 27th, 28th and 29th in the Exposition Hall of the Santa Clara County Fair Grounds on Tulley Road, San Jose. The latest welding processes will be on exhibit. Welded products, welding jigs and fixture displays will be presented by the welding and metalworking industry in the area for educational purposes. Photograph displays of many welded items will be shown by area manufacturers. Free admission by registration.

PLASTIC WELDMENTS

Miami, Fla.—The Executive Committee and regular monthly meeting of the *South Florida* Section were held on January 15th at the Miami Firemen's Benevolent Association Hall.

The speaker at the technical meeting was F. B. Miller, president of Southeastern Distributors, Inc. Mr. Miller spoke on "PVC Plastic Weldments." He spoke very interestingly for 45 minutes at the end of which time he and his assistant set up tanks and plastic rods and many of the members and guests tried their hand at welding the plastic fittings under Mr. Miller's guidance.

SANDER AND PLUMMER VISIT SANTA CLARA

Seated at the head table, at the January 21st meeting of the Santa Clara Valley Section, are 2nd Vice-Chairman R. N. Skow; Membership Committee Chairman, Wm. R. Smith; National Secretary Fred Plummer, Section Chairman M. J. Sebastian, President C. P. Sander, 1st Vice-Chairman A. M. Hubbard, Secretary F. D. Nelson and Arrangements Chairman V. S. Zacharenke

President Sander speaks to the members and guests present regarding Society organization

Mr. Sebastian presents AWS pin to Past-Chairman Fortune Masdeo

UNIVERSITY TOUR

Syracuse, N. Y.—The January meeting of the *Syracuse* Section consisted of a tour of the Syracuse University testing facilities on January 8th. The very interesting tour started at the X-ray facilities of the Research Institute. All members were requested to bring welded samples to be tested during the tour. A plug weld in a clutch plate was X-rayed. The tour continued through the Material Testing Laboratory in Hinds Hall on the main campus. G. Monagle, head of the Material Testing Laboratory, explained the operation of the tensile and bend testing equipment and performed bend tests on welded joints. Syracuse University has complete facilities for testing precast concrete. These facilities were observed and described.

The very interesting tour was enjoyed by all who attended on this cold and crisp January evening.

QUIZ PROGRAM

Toledo, Ohio.—The January meeting of the *Toledo* Section was a very successful "Quiz the Experts" program. The meeting was held on January 21st at the Maumee River Yacht Club. Four teams from the following sections took part in the program: Anthony Wayne, North Central Ohio, Columbus and Detroit. The winner, after nine breathless rounds of concentration on the part of the contestants and judges, was the team from Columbus with a near perfect score of 860 points out of a possible 900.

Members of the winning Columbus team were: Reidar Rasmusen, Charles J. Meinhart, J. E. Lott, R. D. Sopher and Paul Spears. Detroit Section team members were: Buck Schevo, George Brackett, Bill Chase

and Mr. Kessler. Anthony Wayne Section members participating were: Harry Johnson, George W. Laws, James E. McLain and Ken Zimmerman. Joe Henne, Terry Long, Giles Howell, Robert Krueger and Mr. Sherman were the contestants representing the North Central Ohio Section. Sam Snell was "quizmaster" in charge of the program.

HARD SURFACING

Toledo, Ohio.—The Dec. 17, 1957 meeting of the *Toledo* Section was devoted to the subject of "Hard Surfacing."

Gorham W. Woods AWS, engineer for the Arcrods Corp., was the speaker and he presented a very informative and interesting talk. The speaker started his presentation with slides showing the cross section of an etched part, and then further showed the exact spot at higher magnifications. In this manner he was able to explain the microconstituents of steel in general and hard-surfacing materials in particular.

Mr. Woods gave some examples of the best materials for particular uses (carbides for abrasion, austenite for impact, and high-tensile steel for edge holding) and explained how combinations of these "best materials" are necessary for practical applications.

Another interesting aspect of Mr. Woods' talk was his slides showing hardness indentation points in microphotographs, as he was able to explain both the microstructure and the relative hardness of the constituents.

PLANT TOUR

Worcester, Mass.—On January 6th, members of the *Worcester* Section met at Nick's Grille for the usual social hour and dinner. The first speaker was Sidney Low AWS, director of District 1, who outlined the objects and efforts of the SOCIETY.

John Woodman Higgins, chairman of the board of the Worcester Pressed Steel Co., was the next speaker.

Mr. Higgins spoke glowingly of the advantages welding had contributed to the processes, fabrication and assemblies, now accepted as regular procedure in the present-day uses of steel, from which everyone benefits.

He told the meeting that to the best of his knowledge his company was the second company in the United States to employ welding in its shops. While on a trip to Europe shortly after the turn of the century, he had heard of the oxyacetylene torch just developed in France. After being present at a demonstration, he bought an outfit and brought it back with him.

At that time commercial oxygen was unobtainable, so he and one of his employes, a Mr. Braithwaite, had to develop a means of making their own oxygen, as well as to learn the technique of using this "new fangled" method of joining metals. This original torch, now polished to a nicety, is still displayed in a place of honor in the Higgins Armory." Mr. Higgins invited all to visit the Worcester Pressed Steel Co. plant. His invitation was readily accepted and those present proceeded to the plant, where they were joined by 18 or 20 more who had been unable to attend the dinner.

Worcester Pressed Steel Co. is a press shop, making small pressings, of any design, any material, steel, aluminum, magnesium, etc. Its second shift had it working at approximately two-thirds capacity, so that the visitors could witness a lot of complicated draw jobs coming off the presses. Their welding department comprises the spot welders, arc welders, induction brazing, etc., equipment to meet the requirements of an operation of this nature.

Following the tour of the plant, the crowd assembled in the Industrial Museum and Higgins Armory. The John Woodman Higgins Armory, while a hobby of Mr. Higgins, is a Massachusetts chartered nonprofit organization, open to the public five days a week, 8:00 A.M. to 4:30 P.M., with its curator or director, Jeffery Warren, available at all times to explain the various show pieces and to narrate the history connected with many of them. It is regularly visited by from three to four thousand people each month. The museum exhibits in chronological order the development of products from all places and times —the Stone, Bronze and Iron Ages. It has one of the largest and most valuable collections of stained glass and medieval armor of all types in existence anywhere in the world of which Mr. Higgins is justifiably quite proud.

The craftsmanship on these armor pieces, some of them four to five hundred years old, is almost incredible. It is well worth a visit by any present-day mechanic at any time his "ego" begins to expand.

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MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member

D—Student Member E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	175
Members	6,107
Associate Members	6,106
Student Members	184
Honorary Members	9
Life Members	15
Total	12,596

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ALBUQUERQUE

Cutsinger, Lee (B)

ATLANTA

Hrisinko, George (B)

BOSTON

Cameron, Russell G., Jr. (B)
Peterson, Eric G. (B)
Picaso, Andrew A., Jr. (B)
Reddy, Edmund J. (B)

BRIDGEPORT

Watkins, John Halden (B)

CANADA

Breakspear, Frank (B)
Caron, Victor (B)

CAROLINA

Moody, E. O. (B)

CHICAGO

Allred, Edwin F. (B)
Bell, Robert A. (B)
Monroe R., Jr. (C)
Shunt, Peter (B)

CLEVELAND

Eschenhoff, Horst Zum (B)
MacLellan, Daniel A. (C)
Postle, John E. (C)

COLORADO

Aldrich, Lyle G. (B)
Hammond, Leroy (C)
Hasler, Albert W. (C)

COLUMBUS

Jones, Jackson H. (C)
Strohecker, Daniel E. (C)
Young, William Dana (B)

DALLAS

Morton, James (C)

DAYTON

Cox, David Vern (C)
Dunlavy, Raymond (C)
Favorite, Charles W. (C)
Marinello, S. I. (C)

DETROIT

Freese, Jack E. (C)
Gibson, Elmo W. (B)
Johnson, Dean K. (C)

HARTFORD

Atwood, Edwin H. (B)

HOUSTON

Bartosh, Jerold (B)
Haas, Jack M. (B)
Holloman, Robert Howard (B)
Maher, L. W. (C)
Moore, Earl D. (C)
Sheaffer, W. H. (C)
Whitefield, Donald D. (C)

INDIANA

Zima, Clarence W. (C)

IOWA

Kiersey, Thomas A., Jr. (B)

KANSAS CITY

Abbott, Wilbur Newell (C)
Hall, James Robert (B)
Loudon, Clarence Henry (B)
Price, Carl T. (B)

LEHIGH VALLEY

Belbutowski, Ronald A. (C)
Hettinger, Robert W. (B)
Johnson, Herbert H., Jr. (C)
Meixell, Robert A. (C)

LOS ANGELES

Anderson, Frank B. (D)
Anderson, Raymond (D)
Barnes, Kenneth (D)
Berry, Darrell (D)
Brown, Walter E. (D)
Chaney, Larry (D)
Chitwood, Bill (D)
Demarest, Fred (D)
Gleason, William Richard (C)
Harrington, Lani (D)
Harrison, Bill (D)
Helms, Alva (D)
Lown, David (D)
Mayfield, Howard T. (D)
Mayfield, John (D)
Schaefer, Calvin A. (D)
Turner, Joe (D)
Wagner, John H. (D)
Wright, Alton A., Jr. (D)

LOUISVILLE

O'Daniel, Philip B. (C)

MADISON

Brickson, Arthur (C)
Gruhn, Fred A. (C)
Schmid, Arthur (B)
Rinden, Norbert C. (B)
Bellefeuille, Leon J. (C)

MICHIANA

Edwards, Robert B. (C)

MILWAUKEE

Hilber, John J. (B)

NEBRASKA

Mattern, Philip J. (B)
Mossman, Thomas B. (B)

NEW JERSEY

Delisi, Paul Frank (B)
Esmerado, John F. (B)
Pernini, John E. (B)
Purkhiser, Rawlins E. (C)

NEW ORLEANS

Atwood, Harry Joseph, Jr. (B)
Bailey, John H., Jr. (B)
Bourne, E. L., Jr. (B)
Crew, John W. (C)
Ford, William F. (C)
Mabry, William D. (C)
Mitchell, Harry (B)

NEW YORK

Patrowicz, Henry F. (B)
Derrom, Donald L. (B)
Wolfthal, Maurice (C)

NIAGARA FRONTIER

Bullock, Ward E. (C)
Doraski, Stanley (B)
Eberhardt, Ronald P. (D)
Fountain, R. W. (B)
McNeil, Gerald A. (D)
Rodgers, J. Robert (C)
Schmidt, George (D)
Shaffer, Robert E. (C)
Stachura, Victor J. (D)
Stellrecht, Donald H. (C)
Tams, M. Duane (D)

NORTH CENTRAL OHIO

Riblet, Joel P. (B)
Swaim, Dwight (B)

NORTHERN NEW YORK

Gowen, John A. (C)

NORTHWEST

Mull, Bruce D. (C)
Nadeau, Pierre J. (C)
Voit, George (C)

NORTHWESTERN PA.

Buettner, Elmer (C)
Figurski, Edwin L. (B)
Scheppner, A. C. (B)

OLEAN-BRADFORD

Whiting, Douglas H. (B)

PASCAGOULA

Burns, William Vernon (C)
Dupont, Claude Charles (C)

PHILADELPHIA

Adams, Lowell G. (B)
Ehlers, Ralph H. (B)
Fogarty, Richard H. (B)

PITTSBURGH

Hyslop, Andrew, Jr. (B)
Onders, John R. (C)
Sutter, Frederick K. (C)
Zillmann, Rudolf W., (B)

PORTLAND

Foulke, Herbert (C)
Hanberg, Neuman George (C)
Pfiefer, Gilbert (B)

PROVIDENCE

Crouello, Francis (C)
Porter, Forrest L. (C)

PUGET SOUND

Kinney, Robert (B)
Gregoire, Joe O. (B)
Moody, Jack M. (C)
Short, Allen (C)

RICHMOND

Smethie, Hugh B. (B)

ROCHESTER

Gantert, Edward C. (C)

SAGINAW VALLEY

Kober, Fred (C)

ST. LOUIS

Pace, William E. (C)
Punch, J. W. (C)
Randall, R. C. (C)
Randall, R. E. (C)
Riepl, Gustav (B)

SANGAMON VALLEY

Hill, Ben F. (C)
Jackson, Albert L. (B)

Johnson, Robert R. (B)
Osborne, Robert K. (C)
Price, Carlton E. (C)

SANTA CLARA VALLEY

Regan, William M. (C)
Reikes, Alex E. (B)
Reynolds, Charles A. (C)

SHREVEPORT

Creegan, Wm. D. (B)
Cummings, James R. (B)
Reynolds, Howard E. (B)

SUSQUEHANNA VALLEY

Bower, Benjamin F. (C)

SYRACUSE

Mann, Richard L. (B)

TOLEDO

Koos, Lawrence (C)

TULSA

Hudgens, E. A. (C)

WASHINGTON, D. C.

Rasmussen, Paul G. (B)

WESTERN MICHIGAN

Ignasiak, Thomas E. (C)

WORCESTER

Richardson, Shirley S. (B)
Sheehan, Leo F. (B)
Stinets, George N. (B)

MEMBERS NOT IN SECTIONS

Belew, W. Michael (B)
Bowman, W. (C)
Deroo, Albert (C)
Kobayashi, Tojiro Dr. (B)

Members Reclassified

During the month of January

CHATTANOOGA

Mesick, Jack M. (C to B)

DALLAS

Cagle, A. L. (C to B)

DAYTON

Hobart, William H., Jr. (C to A)

MARYLAND

Saxe, Van Rensselaer P. (B to A)

NEW JERSEY

Davis, Norman (C to B)
Minga, Ralph W. (C to B)

NIAGARA FRONTIER

Lyall, Richard G. (C to B)

NORTHERN NEW YORK

Buehner, Fred A. (C to B)

PHILADELPHIA

Morley, William R. (C to B)

PUGET SOUND

Hermon, Robert C. (C to B)

SAGINAW VALLEY

Alcock, James N. (C to B)

SANTA CLARA VALLEY

Goss, Jesse Edwin (C to B)

SOUTH FLORIDA

Hartlee, J. W. (C to B)

NOT IN SECTION

Majumdar, Birendra Nath (C to B)

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225	488	1450
238	500	1500
250	525	1550
263	550	1600
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288	650	1700
300	700	1750
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338	850	1900
350	900	1950
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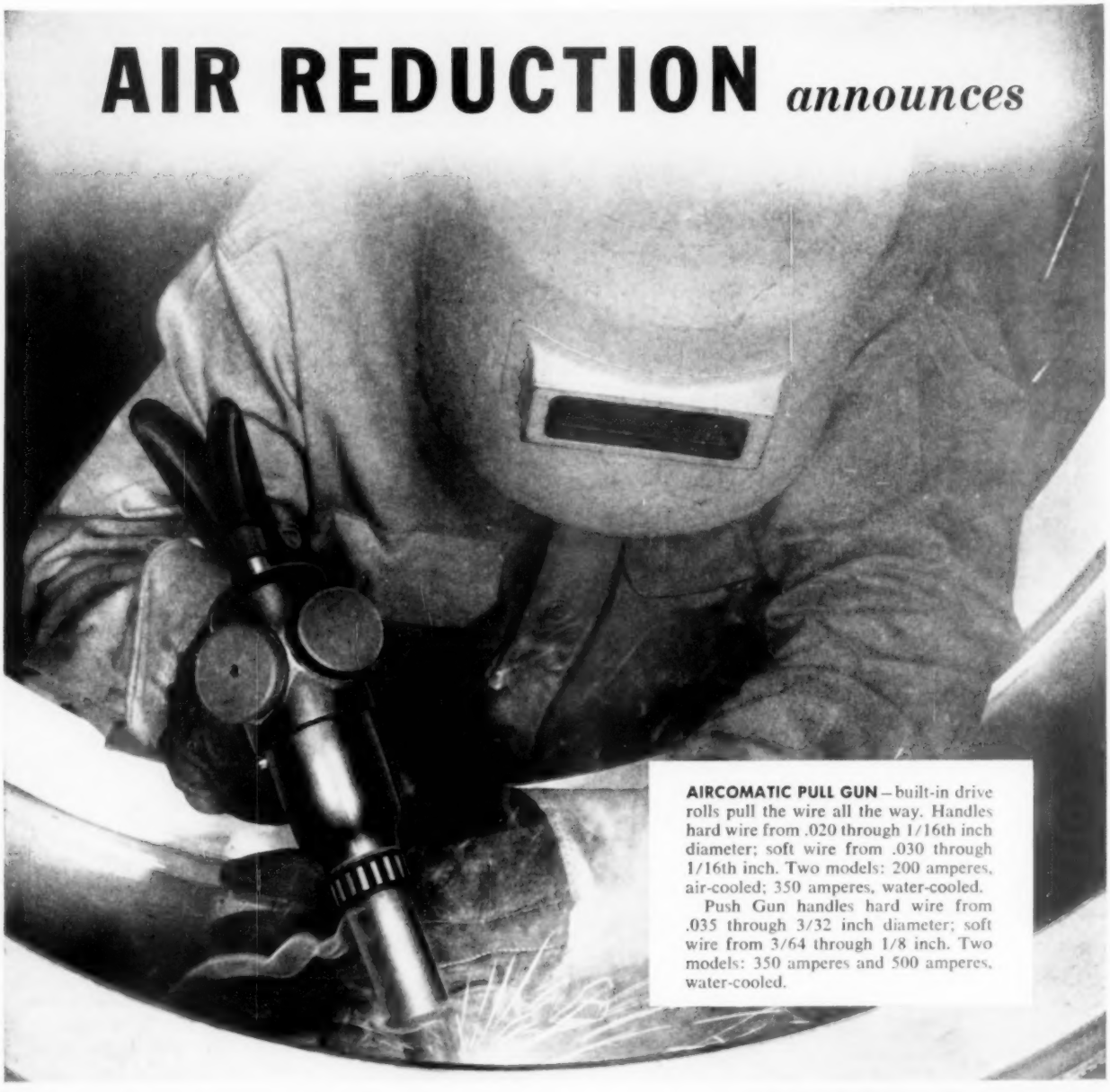

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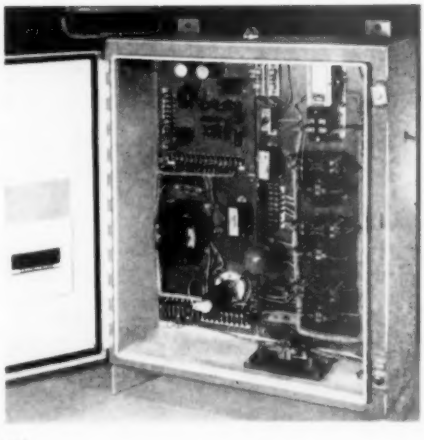

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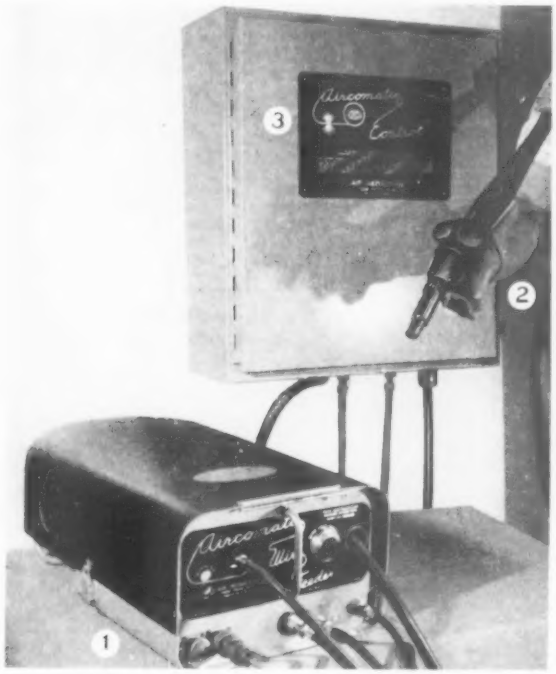

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Current Welding Literature

For copies of articles, write to periodicals in which they appear. A list of addresses is available on request.

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ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,798,937—Multiple Arc Timing System—Howard R. Miller, Clark, N. J., assignor to Union Carbide and Carbon Corp., a corporation of New York.

This arc timing system controls a plurality of arc torches each including a primary and a secondary electrode and means for energizing a pilot-arc between the electrodes of each torch. A timer is provided for connecting each of the primary electrodes to the workpiece and to a source of current for automatically starting in unison a main arc between each of the primary electrodes and the workpiece.

2,803,208—Adjustable Welding Clamps—Arthur A. Bernard and Richard A. Bernard, Chicago, Ill.

This patent on a welding clamp includes a yoke terminating in end portions on opposite sides of a gap formed thereby. A clamp member is carried by each end portion of the yoke with the clamp members being pivoted about fixed parallel axes. Means are provided in the clamp so that one clamp member may indicate the angularity of a workpiece held by one clamp member with relation to a workpiece held by the other camp member when the clamp units are set at corresponding calibrations.

2,803,730—Method of Forming Lined Tubing—Charles M. Kinghorn, Wilmette, Ill., assignor to Kaiser Aluminum & Chemical Corp., Oakland, Calif., a corporation of Delaware.

Kinghorn's method relates to the continuous formation of a plastic lined metallic tubular member. The method includes the steps of securing a film of thermoplastic material to the inner surface of an advancing strip of metal and then progressively shaping the strip of metal into an open seamed tubular member. Thereafter the lined tubular member is passed through an electromagnetic field to induce a concentrated welding current adjacent the seam edges while such seam edges are drawn toward one another until they meet and a weld is effected between metallic portions thereof. Substantially simultaneously with the welding of the seam edges of the metal portions of the tubular member, the free edges of the thermoplastic lining are heated to effect a fusion thereof adjacent the seam of the tubular metal member.

2,803,736—Electrode Mounting for Resistance Weld Tube Mills—Robert J. Barclay, Toledo, and Ralph L. Hankin, Holland, Ohio, assignors to the Etna Machine Co., Perrysburg, Ohio, a corporation of Ohio.

A rotary resistance welder having a welding transformer with a pair of secondary terminal ring members axially insulated from each other is disclosed in the patent. It also includes a pair of wheel electrodes parallel to but spaced axially and insulated from each other, and segmental current carrying rings are provided on the outer sides of the wheel electrodes for intimate abutting engagement therewith. These current carrying rings engage the terminal ring members. Another member including bolt means common to the segmental rings and wheel electrodes is provided and cam devices are actuated by the bolt members for securing the segmental rings in good contact with the electrodes and terminal ring members.

2,803,737—Methods of and Apparatus for Welding to Produce Simple Pressure Butt Resistance Welded Joints—Carl Hubert Parkinson, Littleover, England, assignor to Rolls-Royce Ltd., Derby, England, a British company.

In this method, a member has a plurality of grooves which taper toward the bottom of the grooving to produce a series of spaced lands having dimensions such that the butting surface of another part to be welded can contact several lands during the welding operation. These lands provide a reduced initial area of contact between the butting surfaces and also taper toward the butting surfaces. Initially the other part to be welded is brought into position against the lands with an impact sufficient to bruise the surface of the lands so that full and uniform contact is obtained between the butting surfaces of the parts. Thereafter, the welding current is passed through the parts and they are simultaneously urged together under pressure so that the ungrooved part penetrates into the lands during the welding action against a resistance that increases with the extent of penetration.

2,803,738—Wear-Resistant Contact—William E. Glenn, Schenectady, N. Y., assignor to General Electric Co., a corporation of New York.

In this process, a smooth spherical tip is to be formed on an elongated metal member. The method includes melting an end portion of the member and progressively solidifying the molten portion beginning with an internal volume of metal and ending with a volume at the surface of the molten portion so that the outer molten surface is last in point of time to solidify.

2,803,739—Welding Machine—La Verne F. Bentzen, La Crosse, Wis., assignor to Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

In this arc-welding machine, a plurality of welding heads are positioned on a carrier and means are provided for moving the carrier longitudinally and transversely of the machine. A rotary table is provided and has a radial series of workpiece mounting stations corresponding in number to the workpieces to have weldments provided thereon. A second radial series of workpiece mounting stations are provided in circumferentially disposed relation to the first series of workpiece mounting stations on the rotary table.

2,803,740—Method and Composition for Building Up and Surfacing Austenitic Steels—William J. Hyink, Whittier, Calif., assignor to Stoody Co., Whittier, Calif., a corporation of California.

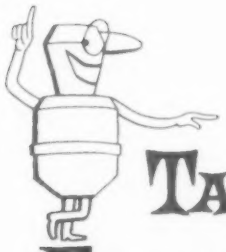
This patent relates to a composition to be fed into an arc weld along with the welding wire. The composition primarily comprises magnetite, ferromanganese and silicon manganese, plus small amounts of other materials.

2,804,408—Process of Treating Tin Bronze—Hardy E. Gregory, Kenosha, Wis., assignor to the American Brass Co., a corporation of Connecticut.

The present patent relates to a method of producing a deoxidized tin bronze having high strength at very high frequencies. The process comprises subjecting a bronze containing 1½ to 12% tin and 0.001 to 0.5% residual deoxidizer, and the balance comprising essentially copper to cold working and then annealing. This produces substantially complete recrystallization without increasing the average grain size to above 0.045 mm. Next the bronze is severely cold worked and annealed without increasing the average grain size to above 0.008 mm. Lastly, the bronze is subjected to plastic deformation to reduce its cross-sectional area by at least 10%.

2,804,536—Device for Automatically Closing Welder Switch—Ronald F. Brennen and James A. Bucci, Brooklyn, N. Y., assignors to Welding Industry Research & Patent Corp., New York, N. Y., a corporation of New York.

The present apparatus relates to a combination including a first transformer having a main primary, an auxiliary primary and a secondary winding. The secondary is connected to a load. A second transformer has a primary of greater impedance than that of the primary of the first transformer and it has a secondary connected to the auxiliary primary of the first transformer. A current source is connected to the primary of the second transformer while a solenoid is connected across the secondary of the first transformer. Other means, responsive to current changes in the solenoid, connect the source of current to the main primary when the current in the solenoid is decreased.



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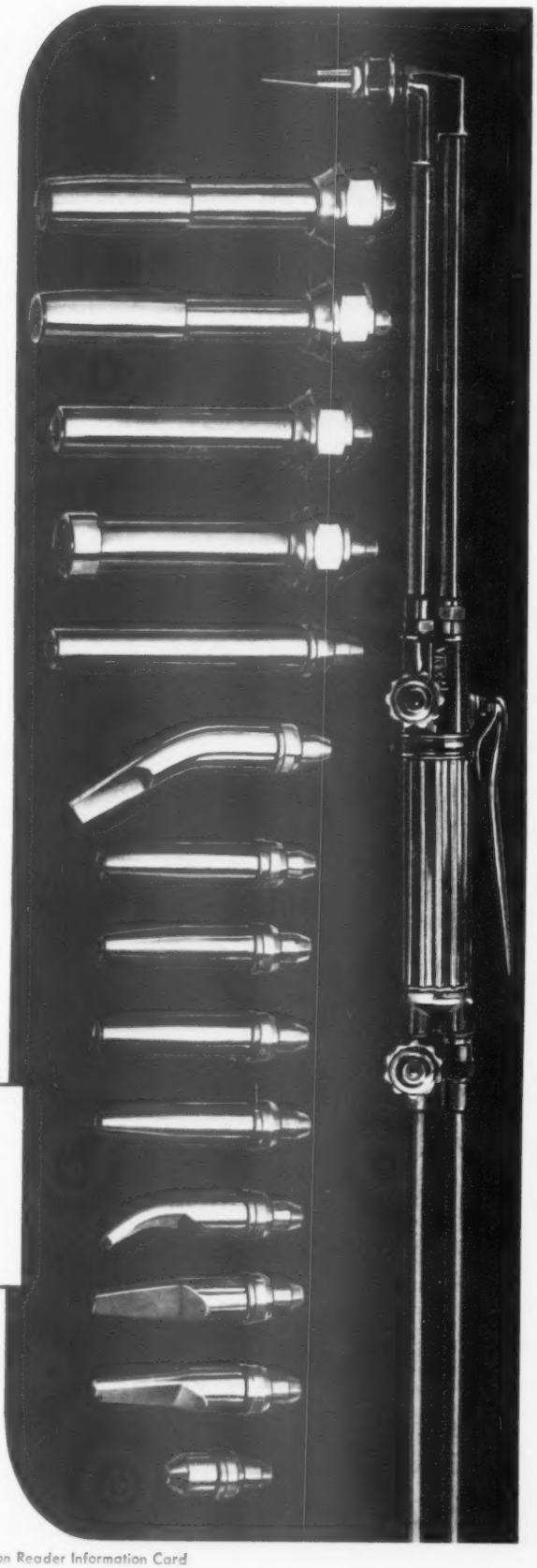

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2,804,836—Internal Alignment Clamp for Girth Welding—Julius B. Tiedemann, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

This patent relates to an internal aligning clamp for use in aligning adjacent ends of two pipe sections disposed in end-to-end relation for welding action. The clamp includes a pluriality of shoes of arcuate contour movable radially outwardly of the apparatus and carried by frame means received within the pipe sections. These shoes bear against the pipe sections to align them for proper welding action.

2,805,152—Steel Alloy Welding Rod and Joint Deposit—Raymond F. Sherwin, North Chicago, Ill., assignor to the Chicago Hardware Foundry Co., North Chicago, Ill., a corporation of Illinois.

Sherwin's patent relates to a welding rod having a specified analysis of small percentages of nickel, copper, sulfur and other materials, between 3.25 to 3.50 carbon, and the remainder comprising iron.

2,805,155—High Temperature Brazing Alloys—Amiel Gelb and George E. Korb, Indianapolis, Ind., assignors to Stewart-Warner Corp., Chicago, Ill., a corporation of Virginia.

This patented brazing alloy consists of about 88 to 97% silver, and about 2 to 10% of a member from the group consisting of platinum, palladium and mixtures thereof, and from about 0.1% to 1% of a member from the group made of nickel, cobalt and mixtures thereof.

2,805,178—Welding Flux Composition—Francis Emery Garriott, West Allis, Wis., assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin.

This new welding flux composition is for use in inert-gas and oxyacetylene welding of bronzes. The flux includes a mixture from about 20 to 100 parts by weight of metal fluorides, from about 5 to 20 parts by weight of an alkali metal fluoroborate and an amount not exceeding 20 parts by weight of alkali metal chloride.

2,805,315—Method of Butt Welding Tubes—Edward C. Chapman, Lookout Mountain, Tenn., assignor to Combustion Engineering, Inc., New York, N. Y., a corporation of Delaware.

In this method, a pair of metallic tubular members are placed with their ends in closely spaced coaxial relation and a sealed annular chamber is formed by telescoped wall members positioned closely about the ends of the tubular members. This chamber then is evacuated and local heating is applied to the extreme ends of the tubular members for heating them to welding temperature and then such ends are forced together.

2,805,316—Apparatus for Electric Induction Welding in a Vacuum—Edward C. Chapman, Lookout Mountain, Tenn., assignor to Combustion Engineering, Inc., New York, N. Y., a corporation of Delaware.

This patent to Chapman covers apparatus for performing the method covered in Patent 2,805,315.

2,805,317—Method for Arc Welding in a Protective Atmosphere—Jean Brillie, Paris, France, assignor to L'Air Liquide, Societe Anonyme pour l'Etude et l'Exploitation des Procedes Georges Claude, Paris, France.

The present patent related to an arc-welding method wherein the electrode is fed toward the workpiece at a rate to maintain the arc and wherein a shielding gas is provided. The patent particularly covers the improvement of using as a portion of the electrode essentially made from iron and where the electrode includes a strand of unalloyed aluminum having a weight equal to from about 0.03 to 0.30% of the total weight of the electrode.

2,805,318—Welding Apparatus—Joseph M. Gladd and George H. Goldner, Warren, Ohio, assignors to the Federal Machine and Welder Co., Warren, Ohio, a corporation of Ohio.

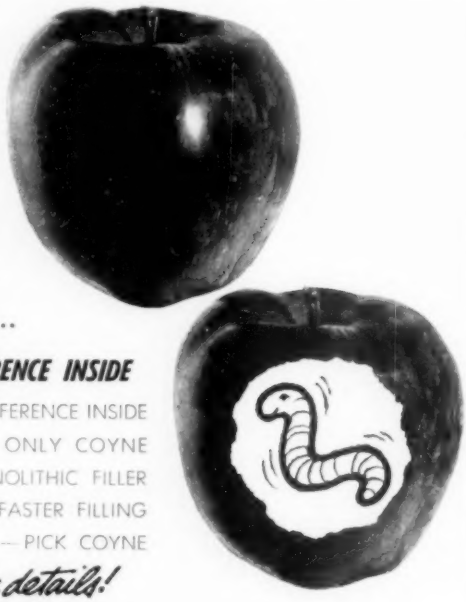
In this patent, the apparatus provides a pair of relatively movable electrodes between which the work is adapted to be positioned and means urge the electrodes in a direction toward each other. Power means are provided to exert a driving force, and a resilient assembly is also present to receive the force and translate it to the electrodes. The apparatus is so constructed that different resilient assemblies of various power values can be quickly positioned in translating relation to the remainder of the apparatus.

2,805,319—Welding Frame—Luther D. Totten, Wilmington, Calif.

This patent relates to apparatus for axially aligning and flash welding the adjacent ends of tubular members and it comprises a special frame for the purpose stated.

2,805,320—Electric Welding Apparatus—Petar Palic, Hamburg, Germany, assignor, by mesne assignments, to North American Philips Co., Inc., New York, N. Y., a corporation of Delaware.

Palic's patent is on apparatus comprising welding electrodes for engaging a workpiece for welding action, which welding electrodes and workpiece provide a path for sonic vibrations. The path has variations in sonic transmissivity as determined by the contact pressure between the welding electrodes and by the physical form of the workpiece. Means supply sonic vibrations at one end of this path and other means are arranged at the other end of the path to produce an electrical quantity having a value determined by the intensity of the sonic vibrations at such other end of the path. Means responsive to this electrical quantity at a first given value thereof initiate the supply of welding current to the electrodes and other means responsive to the electrical quantity at a second given value terminate the supply of welding current to the electrodes.



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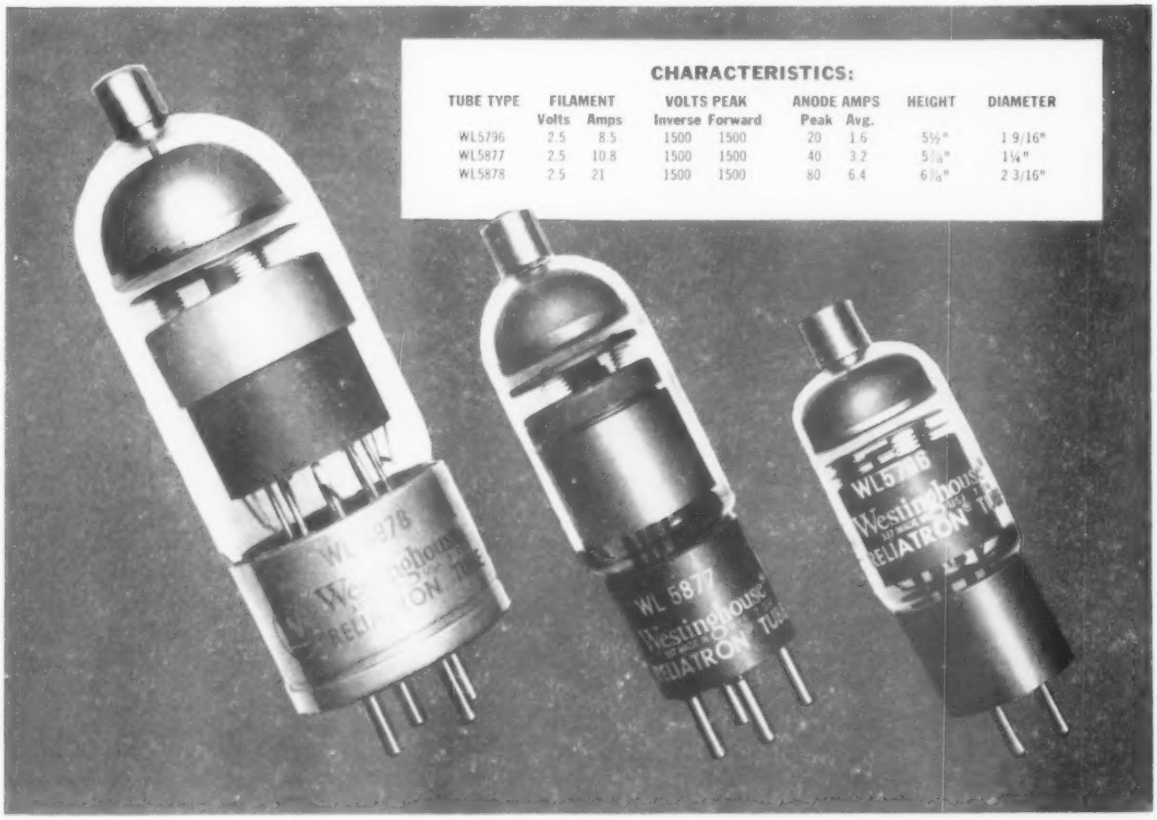

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NEWS of The Industry

Harnischfeger Acquires GE Welder Line

Harnischfeger Corp., Milwaukee, Wis., has acquired the General Electric Co designs for rotating-type welding machines using both gas drives and electric motors. General Electric had through the years developed these designs incorporating the latest refinements in their equipment prior to last July when they ceased operations in this field.

This new addition to the P&H line enables Harnischfeger to provide one of the most complete line of gas drives, motor generators and transformer type welders in the industry.

According to Harnischfeger, the acquisition of this line comes at a time when these highly mobile units will be invaluable for maintenance and construction work along the 41,000-mile route of the new federal highway system. Gas-driven, rotating-type welders are widely used in the heavy construction and pipe-line industries for welding "on the job."

Electric Arc Purchases Universal Welder Corp.

Acquisition of the Universal Welder Corp., Cleveland, Ohio, manufacturers of resistance-welding machines, by Electric Arc, Inc., Newark, N. J., was announced by Joseph Holslag, Electric Arc president.

Purchase of the Cleveland corporation was part of a diversification program by Electric Arc and expands its product line to include spot welders, seam welders, butt welders and other resistance-welding equipment.

Production machinery, patterns and similar properties of the Universal-Welder Corp. are being moved from Cleveland to Electric Arc's Newark plant. Herman Sahli, chief engineer of Universal Welder, will be associated with Electric Arc in a similar capacity.

CWS Plans Welding Convention

The Canadian Welding Society has announced the formation of plans for their Second National Convention and Exhibition.

The two-day convention is planned to coincide with the recently announced National Industrial Production Show of Canada in the Industry Building at the Exhibition Grounds, Toronto, between May 4 and May 8, 1959.

The Society shall form a Convention Committee to organize the presentation of special lectures from prominent Canadian industry spokesmen. Particular attention will be directed to obtaining educational exhibits from all sections of the welding industry to insure utilization of new ideas, materials and techniques in Canada. Participation in the convention is expected from all areas of metal production, with particular reference to the new developing uses of welding in the high strength, high-temperature application of power generation, and aircraft development.

Convention space has been obtained adjacent to the National Industrial Production Show so that convention members may participate in this largest Canadian Industrial Show.

Stanford Adds Metallurgical Engineering

Stanford University, Palo Alto, Calif., has recently announced the formation of a new Department of Metallurgical Engineering. Formerly, metallurgical activities were combined with those in mining and petroleum engineering in the Division of Mineral Technology of the School of Mineral Sciences. Professor O. Cutler Shepard has been appointed executive head of this new department. However, since he is currently on leave, Professor Robert A. Huggins is acting executive head for the academic year 1957–58.

During the last few years there has been a great increase in metallurgical activity at Stanford. A long range program has been undertaken to interest high school students in this field, as well as to bring the opportunities in metallurgy to the attention of students currently enrolled in the university. As a result, the total enrollment at both the undergraduate and graduate levels has increased by a factor of five over the past five years.

In addition, a graduate research program has been developed. Current research in the department includes work on diffusion kinetics in polyphase systems and systems in which a dispersed second phase is being formed. Programs are being undertaken to study the mechanisms by which dispersed phases affect creep behavior, and the effect of solute elements on the mechanical behavior of grain boundaries at elevated temperatures. A fundamental study of some of the factors that control the creep strength of brazed joints is also underway.

In order to accommodate these activities, improvements have been made in the physical facilities of the Department of Metallurgical Engineering. Several pieces of equipment have been acquired for use in teaching and research programs. These include a commercial vacuum-melting and casting furnace, new X-ray diffraction spectrometer and fluorescence-analysis equipment and an additional induction-heating unit.

Ohio State Conference

Fifth Annual Conference for Engineers and Architects—known as ACE Day—sponsored by the Ohio State University College of Engineering, is scheduled for Friday, May 2, 1958, on the campus.

Principal speakers, announced by Engineering Dean Gordon B. Carson, conference director, will be Major General John B. Medaris, commanding general of the U. S. Army Ordnance Corps' Ballistic Missile Agency at Huntsville, Ala.; and James C. Zeder, vice-president, engineering, and special adviser to the president of Chrysler Corp., Detroit.

The topic of the Welding Engineering Department in the technical sessions will be "new concepts in fusion welding."

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1959 Spring Meeting and Welding Show:
May 11–15, Statler Hotel, Buffalo, N. Y.

IAA

March 19–21. Fifty-eighth Annual Convention, Bellevue Stratford Hotel, Philadelphia, Pa.

NWSA

May 5–8. 14th Annual Convention, Americana, Miami Beach, Fla.

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APPLICATION—Either AC or DC, with a choice of straight or reverse polarity on DC. $\frac{3}{16}$" rods weld at 140-220 amps, $\frac{5}{16}$" rods at 225-275 amps. Straight polarity induces very fast burn-off and minimum penetration. Deposits set up rapidly, easily holding edges of welds. Spatter is negligible; overall application efficiency is approximately 78%. No slag covering results, makes easy multiple passes. Complete size range from $\frac{5}{32}$" to $\frac{5}{16}$".

Try Stoody 1030 on your next job – test its position welding advantages and wear resistance...make extra savings with its low cost!

Literature on Stoody 1030 is available from your Stoody Dealer (check the Yellow Pages of your phone book) or write direct.

See our Booth No. 617 at the Welding Show, St. Louis, Mo. April 15–17, 1958

STOODY COMPANY

11986 East Slauson Avenue

Whittier, California

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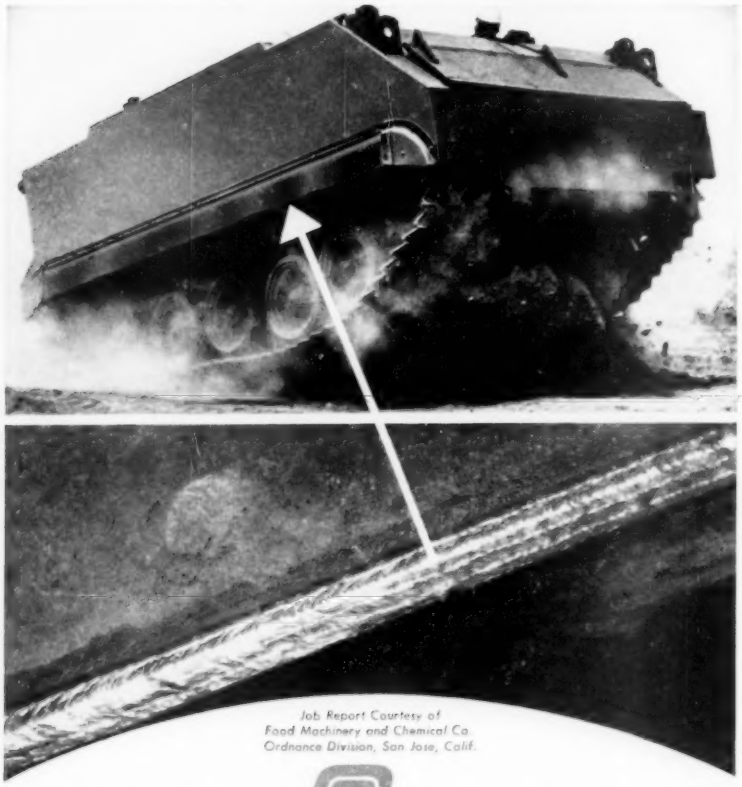
How to produce low alloy welds to resist tons of torture



Job Report Courtesy of
Food Machinery and Chemical Co.
Ordnance Division, San Jose, Calif.

WELD WITH ARCOS

LOW ALLOY ELECTRODES

This 22½ ton armored personnel carrier proves an important point. When working with hard-to-weld low-alloy plate, and welds must be extra strong and tough in the "as welded" condition, it pays to use the highest quality weld metal available. In this case, Arcos Tensilend 100, a low hydrogen coated electrode produced weld metal that matched the physical and chemical properties of the base metal. In addition, it did the job with less nickel than the 19-9 modified electrode formerly used. There was no preheat, no postheat . . . and complete freedom from cracking. ARCOS CORPORATION, 1500 S. 50th St., Philadelphia 43, Pa.

For more details, circle No. 24 on Reader Information Card

NCG Forms New Division

Major changes are announced in the organizational structure of National Cylinder Gas Co., according to Charles J. Haines, president.

Sales and services of industrial gases, welding and flame-cutting equipment will be included in the Chicago-based NCG Division. The division also produces medical gases and inhalation therapy equipment and provides piping design services for hospitals and other institutions.

J. L. Adank

Fred C. Heppel

J. L. Adank has been named president of the division and Fred C. Heppel executive vice-president. Mr. Heppel will also be president of NCG International, new foreign subsidiary, which will operate the company's gas-producing business in Canada, Venezuela, Colombia and other countries.

Activities of the new division include manufacture of oxygen, acetylene, nitrogen, hydrogen and other gases for industrial use. It produces flame-cutting and welding equipment including torches and regulators, multiple-torch flame-cutting machines, portable flame-cutting machines and powder-cutting equipment; also flame hardening, cleaning and paint removing units; scarfing torches; welding and brazing rods; acetylene cylinders and generators; carbide; accessories and equipment. It also produces a-c and d-c welders, inert-arc welders and torches, electrodes and

equipment for the company's new "Dual Shield" welding process.

Westinghouse Announces New Headquarters Posts

Appointments have been announced by management of Westinghouse Electric Corp.'s Welding Department in Buffalo, N. Y.

Named engineering supervisor for automatic equipment, Floyd Adamson will head the design and engineering group responsible for automatic and semiautomatic welding products, including consumable welding wires. In this capacity he will report to Harry J. Bichsel, manager of engineering. Mr. Adamson is a graduate of the University of Buffalo and has been with Westinghouse since 1946.

As supervisor of product planning, Gordon Cossaboom will be responsible for forecasting and interpreting customer requirements for all products of the welding department. He will report to Fred J. Purdy, marketing manager. Mr. Cossaboom joined Westinghouse in October 1957, as coordinator of product service. He holds a bachelor's degree in civil engineering from Northeastern University and master's degree in welding engineering from Ohio State University.

As manager, welding field sales, W. Earle Harwood is responsible for establishing and measuring billings, bookings and expense control performance for sales areas, for distributor franchising and for supervision of certain sales areas.

With Westinghouse since 1947, Mr. Harwood formerly served as product manager for electrode sales at the department's headquarters in Buffalo, N. Y.

The Messrs. Adamson, Cossaboom and Harwood are members of the American Welding Society.

Bureau of Shipping Elects

The 96th Annual Meeting of the Board of Managers and the Members of the American Bureau of Shipping was held in the Bureau's board room, 45 Broad St., New York City.

Walter L. Green, chairman of the board, presided.

The following officers were re-elected: Mr. Green as chairman of the Board of Managers; David P. Brown, president of the Bureau; Jerome B. Crowley, senior vice-president; Lewis C. Host, vice-president—operations; Arthur R. Gatewood, vice-president—engineering; Alfred Blum, treasurer and Daniel L. Parry, secretary. Also re-elected were Assistant Vice-President Harold M. Wick; Kurt Molter, assistant treasurer, and William H. C. Seelig, assistant secretary.

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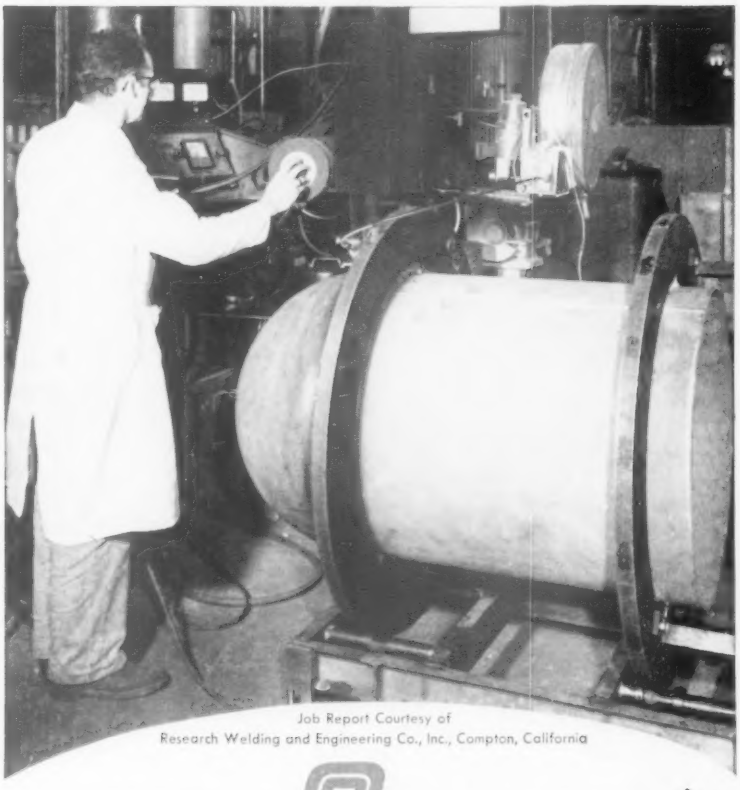
Get X-ray quality welds



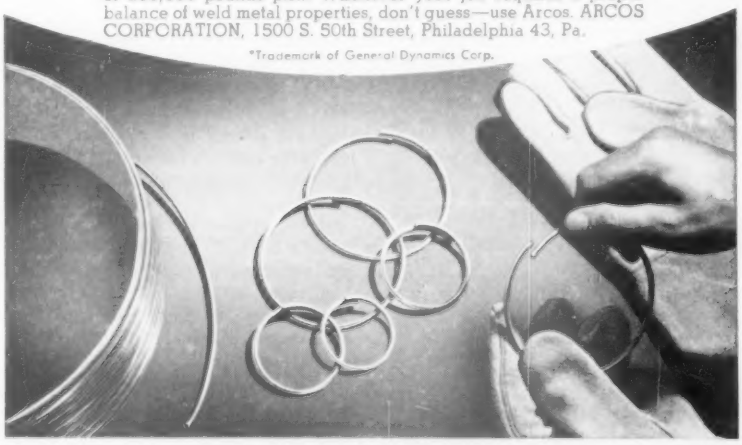
Job Report Courtesy of
Research Welding and Engineering Co., Inc., Compton, California

USE THE ARCOS

EB* WELD INSERT

This welded missile tank had to weigh less than 600 pounds and yet contain air under pressure of 3,000 p.s.i. Arcos EB* Consumable Weld Inserts were used in automatic inert gas arc welding of the dished heads to the tank body. The inserts saved weight by eliminating back-up rings. They also allowed welding to be done conveniently from one side only and produced 100% x-ray quality root passes. Chromenar CMV coiled wire for submerged arc welding was used to complete the welds. After heat treatment the welds matched the base metal, with tensile strength in excess of 200,000 pounds p.s.i. Whenever your job requires a proper balance of weld metal properties, don't guess—use Arcos. ARCOS CORPORATION, 1500 S. 50th Street, Philadelphia 43, Pa.

*Trademark of General Dynamics Corp.



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INTERNATIONAL WELDING NEWS

By Dr. Gerard E. Claussen

The average reader of THE WELDING JOURNAL realizes that activity in welding is becoming increasingly intense in this country. He reads the JOURNAL to keep abreast of progress. He also is aware that the tempo of welding activity is rising in foreign countries. Hitherto, the JOURNAL has published abstracts of many important foreign articles as well as complete articles by authors from foreign countries.

The volume and quality of foreign welding periodicals, of which every country publishes at least one, have been increasing to an extent that systematic coverage in THE WELDING JOURNAL seems in order. To best accomplish this, "International Welding News" will henceforth present digests of important technical articles on welding in foreign-language publications. It will highlight the outstanding foreign advances in welding fabrication and in research on physical, mechanical and metallurgical subjects. Also, it will, from time to time, include brief reports on other world-wide activities of unusual interest to the American welding industry. No attempt will be made to cover foreign patents.

MEETINGS

Netherlands Hold Welding Symposium

The Netherlands Welding Society held its 1957 Symposium in Utrecht, October 9th and 10th on the topic "The Metallurgy of Welding Steel."[1] The first papers dealt with the physical phenomena of the arc itself, including films on metal transfer by L. F. Defize and P. C. van der Willigen. Papers on oxygen, nitrogen and hydrogen in welds were given by J. D. Fast, P. C. van der Willigen and G. Westendorp. There was considerable discussion of the extent to which CO reaches equilibrium and of the necessity for taking into account oxygen in inclusions. J. D. Fast discussed his theory that sulfur concentrates on the surfaces of the growing crystals and acts as a catalyst in gas reactions. Since the first symposium in 1938, the effect of gases on aging has been discussed, yet there was still disagreement on this subject in the present meeting.

Next were papers by W. P. van den Blink on slag-metal reactions in arc welding, and by G. Westendorp on the effect of base metal on weld quality. The latter paper emphasized the importance of local segregations not taken into account by some welding specifications. G. E. Tummers discussed the carbon equivalent of several alloying elements from the standpoint of hardening of the heat-affected zone. There was lengthy discussion of the effect of the high yield strength of weld metal compared with the low yield strength of plate. Professor Soete believed that, while tests at room temperature revealed no effect, tests at low temperature might reveal effects due to high yield point, especially with tensile residual stress. The last paper dealt with distortion and cracking due to welding. Crack tests and low-hydrogen electrodes were discussed.

MATERIALS

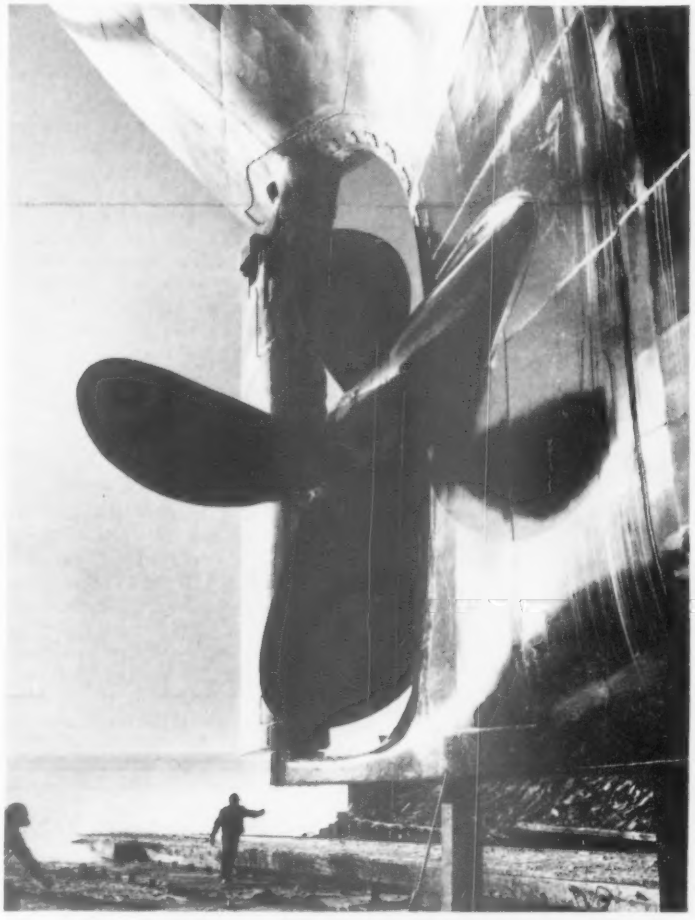
Germany Standardizes Aluminum-Magnesium Alloys

Two aluminum-magnesium alloys have been standardized for shipyard use in Germany: $AlMg_3$ and $AlMg_4$ containing 2.3-3.5 and 4.3-5.5% Mg, respectively. A proposal to substitute one alloy $AlMg_4$ for the two has been evaluated experimentally by P. Brenner.[2] Special materials were melted and processed for this investigation (see Table 1). The sheets were 0.06 and 0.08 in. thick and were welded by both argon arc and oxyacetylene processes.

The investigation showed that 3 years' corrosion testing in sea water caused relatively little drop in 0.2% yield strength, tensile strength and elongation in either alloy in any treatment, welded or unwelded. Sea water caused a protective layer to be formed which is believed to have protected the Beta phase and thus prevented the intergranular corrosion observed in 3-yr weather exposure tests of unwelded specimens. In stress-corrosion tests only the D treatment of $AlMg_4$ failed. All other specimens, including welded specimens, did not fail in 9 mos. Earlier work

Dr. Gerard E. Claussen is associated with the Linde Co., Newark, N. J.

Heavy sections like rudder posts and propeller blades can be gamma ray inspected with ⅓ shorter exposure—and welded seams can be radiographed more rapidly with available portable or low kv x-ray equipment—when Kodak Industrial X-ray Film Type KK is used.



. . . cut exposure time 1/3 with New Kodak Industrial X-ray Film

TYPE KK

Where heavier sections are to be radiographed or where the output of available x-ray or gamma ray sources is limited, Kodak's new Industrial X-ray Film Type KK is the film to use.

This film shows as much as 50% increase in speed over the well-known Type K Film. It means more work can be done—that exposures can be cut by a third. And those who have tried Type KK tell us that its higher contrast, offsetting a slight increase in graininess, provides improved radiographic sensitivity.

To learn how Kodak Industrial X-ray Film Type KK can extend the service of your present radiographic equipment, get in touch with your x-ray dealer or Kodak Technical Representative.

EASTMAN KODAK COMPANY
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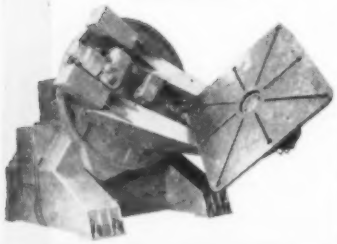
something new from



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The customer said, "We want to make two girth welds on a 10,000# piece at 90" without two setups." The unusual job was done . . . engineered and produced . . . by Berkeley-Davis. Find out why Berkeley-Davis can make any standard or special positioner, regardless of size or shape . . . from the smallest to the largest, with a performance standard that can't be excelled. Write today for your special or standard requirements.

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Table 1—Al-Mg Alloys Used by Brenner

	Composition, %				
	Mg	*Mn*	*Fe*	*Si*	*Cu*
$AlMg_4$	3.94	0.45	0.17	0.11	<0.01
$AlMg_5$	5.02	0.45	0.17	0.11	<0.01

Treatment:

A, slowly cooled in the furnace (90° F per hour) after 8 hr at 896° F.
B, water quenched after 8 hr at 896° F.
C, same as A but cold rolled 20%.
D, same as B but cold rolled 20% and held 14 days at 212° F.

with $AlMg_2$ alloy also showed that welding did not affect the resistance to corrosion or stress corrosion. Slow cooling and the addition of 0.1 to 0.3% chromium improve the stress corrosion resistance of the Al-Mg alloys.

The general conclusion was that $AlMg_4$ has lower strength and greater tendency to crack during welding than $AlMg_5$ without the superior forming characteristics and low price of $AlMg_5$.

DEVELOPMENT

Power Supplies for CO_2 Welding Behind the Iron Curtain

A report from the East German Welding Institute[3] and another from a Russian laboratory[4] stress the importance of a flat as against a drooping characteristic. The East German report gives the results of oscillographic and motion picture records of CO_2 arcs with steel electrodes using three different generators with flat, weakly drooping and strongly drooping static characteristics. In one series of tests, beads were made over sharp steps in the work. In another series the speed of the wire feed motor was suddenly decreased up to 8%. Under both conditions changes in arc length were smaller with the flat than with the drooping characteristic. It was concluded that for fully automatic welding, disturbances will cause minimum changes in arc length if the characteristic rises slightly to the same extent as the CO_2 arc itself: 3 v per 100 amp.

The paper by K. K. Krenov states that porosity and spatter in CO_2 consumable-electrode welding is not due primarily to gas purity or wire composition, but to changes in arc length. The short arc required for low porosity and spatter is obtainable with constant wire speed using a rising characteristic. Generators are described with adjustable series field to secure desired rising characteristics.

Netherlands Improve Rail Joint Welding

Two recent articles describe developments in rail joint welding which is accomplished in Holland, at any rate, either by resistance welding in the shop or by thermit welding in the field. In 1955 the Netherlands Railways welded 19,100 joints electrically and 1700 joints by thermit. W. Ahlert[5] describes a method of shortening the preheat time for a thermit joint by feeding through the rail head. G. Zoethout[6] describes a mold welding process for joints with sawed ends spaced 3/8 in. apart and welded with a special low-hydrogen electrode developed by Philips. The time per joint is 20 min. Both the thermit and arc welded joints have satisfactory fatigue and impact strengths.

HISTORY

On the fiftieth anniversary of the Kjellberg patent, the first on covered electrodes, F. Wortmann,[7] a Swiss engineer associated with the electrode industry for 35 years, writes a concise history from the European standpoint. Kjellberg's patent referred particularly to the necessity for the coating forming a crater at the end of the electrode to guide the metal globules in overhead welding. Subsequent extensive litigation was concerned with establishing the requisite thickness for this effect and overlooked the fact that the composition of the coating was more influential than its thickness. Another misconception that retarded the introduction of covered electrodes was the belief that the thicker the coating, the more slag inclusions the weld retained.

Low-hydrogen electrodes are traced back to the lime-fluorspar paste used between asbestos windings in 1918, and to the Sarazin-Moneyron discovery in France in 1934 of the importance of high-temperature drying. The iron oxide E6020 type developed from arc exothermic coating designed to retard the cooling of the weld. It was the first type of covered electrode to attain plate quality (1926). Rutile types were developed from the E6020 by substituting ilmenite for iron oxide, which permitted savings in manganese.

Welding transformers were originally built in Germany in 1922 and at first required the "oxidizing" low-voltage type of coating developed in 1923. Extrusion presses were used before 1920 to form the paste around asbestos-wound electrodes, and were used in 1926 by the Swiss firm of Secheron for electrodes

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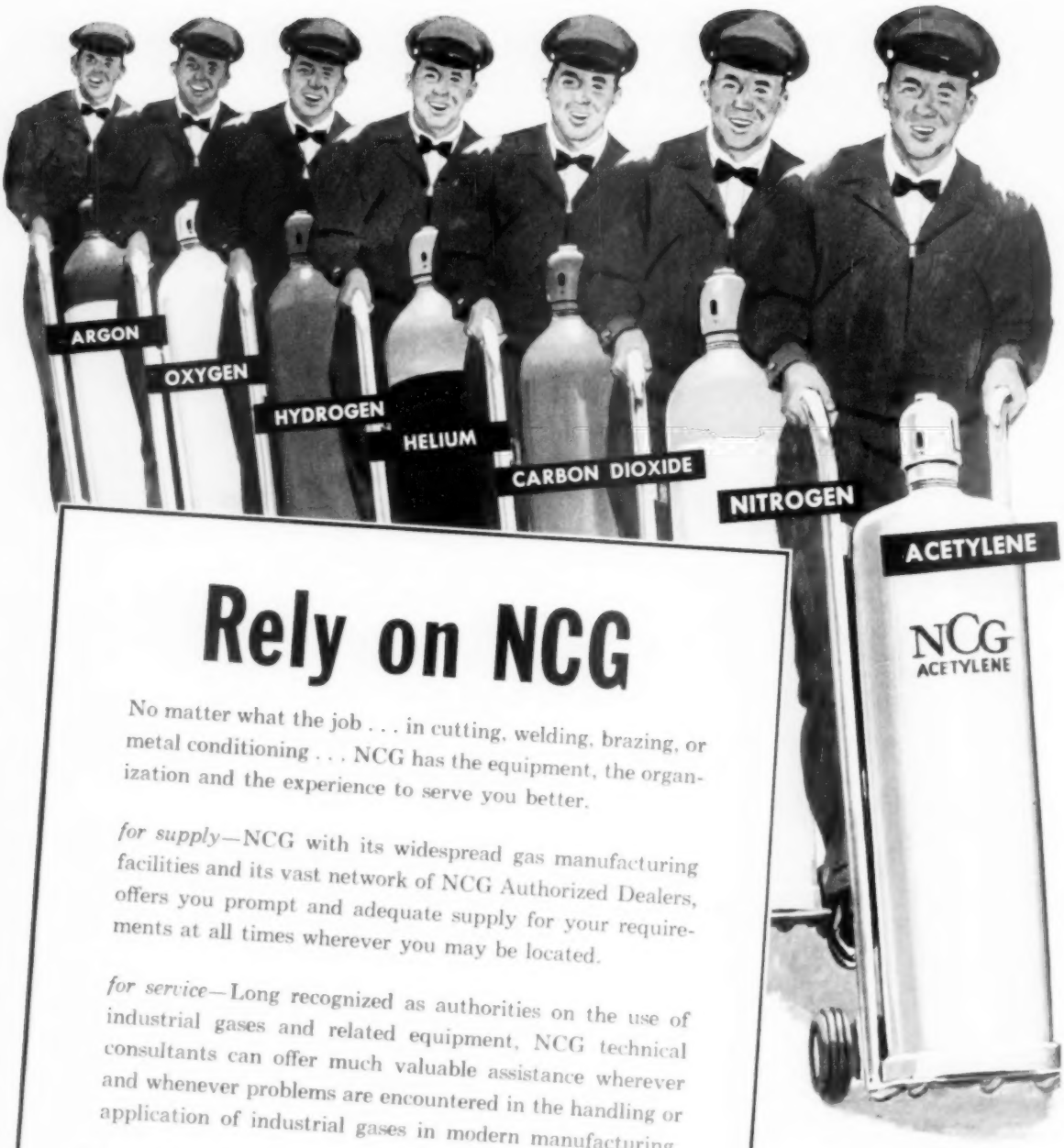

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No matter what the job . . . in cutting, welding, brazing, or metal conditioning . . . NCG has the equipment, the organization and the experience to serve you better.

for supply—NCG with its widespread gas manufacturing facilities and its vast network of NCG Authorized Dealers, offers you prompt and adequate supply for your requirements at all times wherever you may be located.

for service—Long recognized as authorities on the use of industrial gases and related equipment, NCG technical consultants can offer much valuable assistance wherever and whenever problems are encountered in the handling or application of industrial gases in modern manufacturing.

for satisfaction—NCG pioneered in industrial gases and early realized dependable and uniform gas quality was a basic industry need. Gas users have found they can rely on NCG, and NCG cylinders are a familiar sight throughout industry today. If you have plans for new uses of industrial gases or any problems in their present use, consult with NCG.

© Copyright 1958, National Cylinder Gas Company

Fabricator of gasoline storage tanks reports that DUAL SHIELD process has reduced welding costs by 25 per cent.

Manufacturer of truck bodies found that ARGONARC process produced welds three times faster than former manual method, reduced production costs and increased plant capacity.

Now! Better welds at lower costs than ever before possible

Since the cost of welding is a major factor in your operations, here is news that can have an important bearing on your future profits. Two new NCG welding processes—DUAL SHIELD* for mild steel and ARGONARC* for stainless steel and all other weldable metals—have proved in actual use they can reduce welding costs to record-breaking low levels.

Both processes use the same NCG equipment—basically a control and wire drive unit used either with the NCG Automanual* welding gun or the NCG automatic torch. DUAL SHIELD welding is done with inexpensive CO_2 gas fed to the arc to blanket the weld and a special flux-cored electrode which is fed automatically and continuously from a reel. ARGONARC welding uses coiled welding wire and argon as the shielding gas.

Using the Automanual welding gun with DUAL SHIELD electrode, a welder can deposit from four to five times as much weld metal as with conventional manual electrodes. Penetration is deeper, welds are of high quality and slag is practically self-removing. The ARGONARC process offers comparable advantages. In both processes, welding efficiency is further increased by using the automatic torch.

Ask the NCG office in your area to show you what these new processes are doing for others. Or write for informative literature.

ARGONARC, DUAL SHIELD and Automanual are National Cylinder Gas Company trademarks.

Complete and helpful literature is available to you on request. There is no obligation. Simply fill out and mail this coupon.

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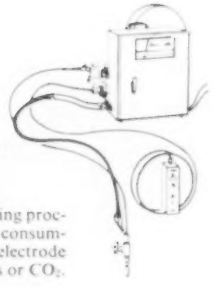

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For arc welding processes using consumable wire or electrode with inert gas or CO_2.

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AC welders, DC rectifier welders, AC-DC welders, constant voltage welders, inert arc welders, portable DC welders, portable spot welders.

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Welding rods and brazing alloys—steel, alloys, non-ferrous metals. Electrodes—mild steel, low alloy steel, low hydrogen, iron powder, stainless steel, cast iron, aluminum, monel. Hardfacing alloys. Spooled wire and electrode for automatic welding.

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Welding and brazing torches, soldering torches, welding and heating tips, regulators.

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Cutting torches, cutting attachments, cutting tips, gouging and rivet washing tips, regulators, flame washing torches, powder cutting torches, dispensers and ferrous powder.

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Cut-O-Matic®—lightweight, portable machine. Type "JR"—medium duty stationary machine. Type "R"—heavy duty, multiple torch stationary machine. No. 300—for cutting heavy scrap, castings, skulls, etc.

ACCESSORIES
Gas welding hose, arc welding cable, electrode holders, cable connectors, hose fittings, helmets, goggles, protective clothing, flux, torch lighters, cylinder trucks, weld cleaning tools, positioning clamps.

OTHER EQUIPMENT
Flame cleaning and paint removing burners, flame hardening equipment, scarfing torches, acetylene generators, CO_2 heaters, catalytic gas purifying units.

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without winding at the rate of 50 electrodes per minute. Patent numbers and dates are supplied by the articles in many instances, including an automatic welding machine patented in 1890 and a hydrogen-protected welding arc patented in 1915.

RESEARCH

Schnadt Develops Two New Methods of Testing

A new type of specimen[1] for testing for tendency toward hot cracking and a new type of brittle fracture specimen[2] for steels have been developed by H. M. Schnadt. The hot cracking specimen consists of a butt joint clamped in a rigid frame. A weld bead is deposited in the joint, which then is broken open with hammer blows to evaluate the extent of cracking as a percentage of the total length of the weld. The steel may be 0.04 to 1½ in. thick with the gap between plates up to ¼ in. The particular advantages of the specimen are simplicity and reproducibility. Results reported by the author show that the specimen distinguishes between rutile and low-hydrogen electrodes, between low and high-sulfur plate and between electrode core rods containing 0.018 and 0.040% sulfur. The specimen is said to be suitable for other crack testing.

The brittle fracture specimen is a slow-bend specimen similar to that proposed by Van der Veen. It differs from the latter in having a hole ⅛ in. in diam drilled at mid-depth of the 3½-in. deep specimen. The width of the specimen is plate thickness. The distance between supports is 10 in. and the V notch is 0.20 in. deep. The hole is the essential feature of the specimen. It localizes fracture to the portion of the specimen stressed in tension, and prevents diagonal wandering of the crack.

STRUCTURAL

Welded Aerial Cable Car System Spans the Rhine

An aerial cable car system[10] has been built across the Rhine river at Cologne. The supports for the system stand on each bank and are all-welded. One tower is 130 ft high (39 tons), the other is 120 ft high (36 tons). Each tower was built in four sections in the shop and the sections were welded together at the site partly on the ground and partly in the air. The box sections were made of plates 5/16 and ⅜ in. thick. All stiffening is internal so that the towers present a smooth external appearance.

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EUTECTIC HOLDS OPEN HOUSE

Part of large crowd who turned out to watch live arc and torch demonstrations of latest metal joining techniques at recent three-day "open house" of Eutectic Welding Alloys Co., Pacific Division, Inc., new Warehouse Service Center at 5348 Jillson St., Los Angeles, Calif.

←For more details, circle No. 29 on Reader Information Card

Philadelphia to Host IAA Convention

With a program designed to interest a broad industrial audience, the 1958 Convention of the International Acetylene Assn. will open Wednesday, March 19th, at the Bellevue-Stratford Hotel, Philadelphia, Pa.

Featuring Technical Sessions on the themes of construction, transportation and safety in specific areas of interest, the IAA program will run through Friday, March 21st, offering a total of nine technical papers on subjects ranging from the technology of piping acetylene to the various uses of oxyacetylene processes and related safety factors.

The first technical session, scheduled for Wednesday afternoon following the opening luncheon, has been planned to appeal particularly to engineers and management men in the chemical and refining fields. The session will include papers on the piping of acetylene under pressure, and the use of the oxyacetylene flame in plant construction.

Thursday morning's technical session will put more stress of applications in the metalworking industries with papers on automobile frame, and railroad car manufacture, and on mechanized hard surfacing with the oxyacetylene flame.

An entire session on Thursday afternoon will be devoted to the general theme of safety with papers scheduled on accident and fire prevention, mutual disaster programs and the development of safety standards for acetylene equipment—an insurance study.

In general, the content of the program will have specific appeals to industrial management, engineers and safety technicians in the metalworking, chemical, construction and transportation industries. Final feature of the convention will be an inspection trip to the Philadelphia Navy Yard Friday afternoon.

P&H Appoints Chicago Distributor

The Harnischfeger Corp., Milwaukee, Wis., has announced the appointment of Ardagh Welding Supply Co., 4626 W. Lawrence Ave., Chicago, Ill., as a distributor of P&H welding equipment and supplies.

PERSONNEL

Doty Promoted

W. D. Doty has been promoted from research engineer to division chief of the Bar, Plate and Forged Products Division of U. S. Steel's Applied Research Laboratory. Dr. Doty is a member of the AMERICAN WELDING SOCIETY.

Quinlan Named by Airco

E. A. Quinlan, salesman for the Minneapolis district of Air Reduction Sales Co., has been appointed assistant sales manager of that district it was announced by D. F. McCandlish, regional sales manager, midwestern region.

Mr. Quinlan has been with Airco for more than twenty years, starting as a service man at Minneapolis in 1937. In 1944 he became a railroad mechanical specialist, working out of Chicago, and in 1946 he was assigned to the Minneapolis district as a salesman.

Clark Named President of Wall Colmonoy

W. P. Clark has been named president of Wall Colmonoy Corp. in a recent action of the company's board of directors. In the same action, A. F. Wall, founder of Wall Colmonoy and former president, assumed duties as chairman of the board.

W. P. Clark

Mr. Clark is a graduate of the University of Detroit. Following service in the United States Navy as a lieutenant in charge of destroyer radar operations, he joined Wall Colmonoy's New York office as a sales engineer in 1946. He moved to the Detroit home office in 1948 as assistant sales manager and became sales manager in 1950. Mr. Clark

A. F. Wall

became vice president in charge of the company's Colmonoy Division in 1953, a position he held prior to this promotion.

Mr. Clark is a member of the AMERICAN WELDING SOCIETY.

De Santo Promoted

Joe De Santo, who joined the sales staff of the Champion Rivet Co. in June of last year, has been appointed their manager of Welding Sales—Chicago Section as of January 1st.

Mr. De Santo is a member of the AMERICAN WELDING SOCIETY.

Jensen Promoted by Alloy Rods

F. L. Blodgett, general sales manager for Alloy Rods Co., announced recently the appointment of Arnold C. Jensen as field representative in the Los Angeles area. He will take over the territory formerly managed by John Pierce, who has been named western sales manager. Mr. Jensen will also work with distributor organizations in Southern California, Arizona and western Texas.

Arnold C. Jensen

Mr. Jensen is a member of the AMERICAN WELDING SOCIETY.

Cook Appointed by Page Steel

H. W. Cook, Jr. has been appointed to the position of district sales manager, Page Steel & Wire Division, American Chain & Cable Co., Inc., Monessen, Pa., according to an announcement by Joseph N. Kemple, sales manager. Transferred from the New York sales district to Houston, Tex., Mr. Cook will make his new headquarters at 630 McFarland St., Houston 1.

H. W. Cook, Jr.

A graduate of the University of Vermont, he joined ACCO in 1952 as a sales representative for the Page Division.

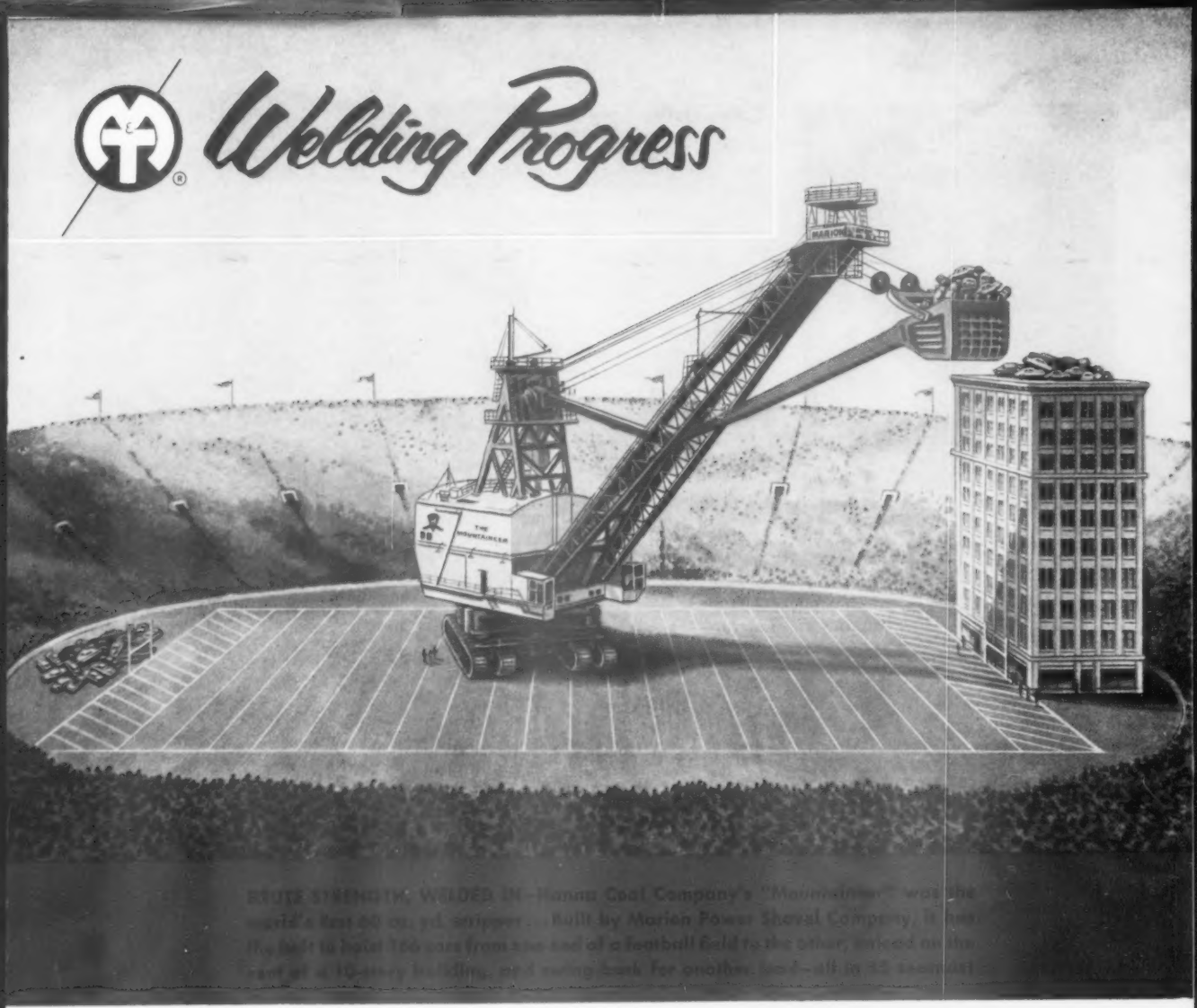
Mr. Cook is a member of the AMERICAN WELDING SOCIETY.

Bennewitz Made Assistant Manager

Robert H. Bennewitz has been named assistant manager—Railroad Department according to announcement by K. I. Thompson, manager—Railroad Department, Linde Co., Division of Union Carbide Corp.

Mr. Bennewitz joined Linde Co. as a development engineer in 1941 following his graduation from the University of Wisconsin where he received the Bachelor of Science degree in mechanical engineering. In 1942 he moved to the company's Milwaukee office as district engineer with the responsibility of assisting many industrial plants in setting up production welding procedures. He was subsequently promoted to process service supervisor. Mr. Bennewitz was assigned to the company's Detroit office in 1945, and became process service

Welding Progress



Murex® Electrodes Help Build Muscles Like This!

Much of the brawn of this 5,500,000 lb. mining giant that continuously scoops 90 tons of mountain without tiring, was knitted with Metal & Thermit arc welding electrodes.

Speedex HTS, and Types HTS-18 and DM electrodes were used for *all* manual welds of the main frame structures, boom and gantry . . . Hardex 45 was used to hard surface the boom socket ears to resist impact and wear from the boom. The Mountaineer's round-the-clock performance since January, 1956, has led to the construction of four similar machines, all identically "muscle-powered" with M&T electrodes.

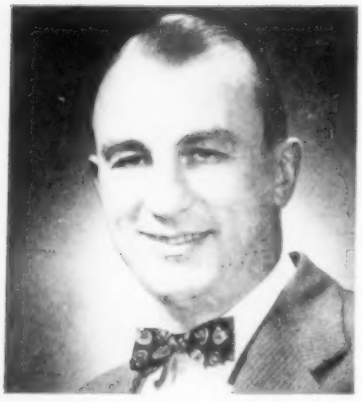
Selecting the right electrode for any of its line of excavators is no problem for Marion. Metal & Thermit's complete line for all welding applications can be applied to any of Marion's machines for sound, reliable, low-cost welds.

Whether you join thin sheet or heavy sections . . . fabricate or repair structures of special, mild or low alloy steels or other metals, there is a large selection from M & T's MUREX line of mild steel, iron powder and hard-surfacing electrodes to meet your requirements. Write for your copy of our helpful Electrode Selector . . . an easy reference for selection of the correct electrode for any application.

METAL & THERMIT CORPORATION

GENERAL OFFICES: RAHWAY, NEW JERSEY

For more details, circle No. 30 on Reader Information Card



R. H. Bennewitz

supervisor in 1947, and assistant district manager in 1951. He then moved to Kansas City, Mo., where he served as assistant southwestern region manager of Engineering Service, and assumed his most recent position as southwestern region manager of Engineering Service in 1955.

Mr. Bennewitz is a past-chairman of the Detroit Section of the AMERICAN WELDING SOCIETY, and an active member of American Society for Metals, Association of Iron & Steel Engineers and the Society for the Advancement of Management.

Grotke Appointed

Gordon E. Grotke has been appointed a technologist in the Welding Section of the Bar, Plate and Forged Products Division of U. S. Steel's Applied Research Laboratory in Monroeville, Pa.

Gordon E. Grotke

Mr. Grotke received his bachelor's and master's degrees in metallurgical engineering from Rensselaer Polytechnic Institute and comes to U. S. Steel from Scinky Bros. Research Laboratory, Los Angeles, Calif. He is a member of the AMERICAN WELDING SOCIETY.

Carey Joins Borg-Warner

Julian D. Carey has been appointed welding engineer for the York Division, Borg-Warner Corp., York, Pa. In this capacity he will coordinate welding activities for the full line of York Division products.

Prior to this assignment Mr. Carey was associated with the General Electric Co.'s Welding Department as metallurgical engineer. He has presented a number of papers on CO_2 welding and has been active in the York-Central Pennsylvania Section of the AMERICAN WELDING SOCIETY.

Heffron Named by Pureco

N. L. Heffron, district manager of Pure Carbonic Co., a division of Air Reduction Co., Inc., Newark District, has been appointed regional sales manager of the northeastern region, it was announced by W. A. McCleary, regional manager.

N. L. Heffron

Mr. Heffron joined Pureco in 1934 as a warehouse supervisor. He became a salesman in 1935, branch manager at Newark in 1945, assistant district manager in 1948 and district manager in 1952.

Brown Joins New Orleans Firm

Ralph Brown has been appointed general manager of Industrial Air Products Co. of the South, New Orleans, La., it was announced recently by Gilbert Schnitzer, president.

Mr. Brown has previously been associated with the Delta Oxygen Co., Memphis, Tenn., and was owner of the Southern Welding Supply Co. for several years.

Bruno and Wilson Promoted by Airco

Two personnel changes in the New Orleans district of Air Reduction Sales Co. have been announced by H. C. Wallace, regional sales manager of the southern region.

S. A. Bruno has been appointed district manager to replace L. F. Bruno who has retired after 38 years of service. S. A. Bruno joined Airco in 1929 at New Orleans, and was made assistant sales manager in 1930, a post he has held up to this time.

F. T. Wilson, Jr., formerly a salesman in the Louisville, Ky., district, has been named assistant sales manager in New Orleans. Mr. Wilson started with Airco in 1947 as a technical sales representative in Louisville, and became a salesman there in 1955.

The Messrs. S. A. Bruno and Wilson are members of the AMERICAN WELDING SOCIETY.

OBITUARY

Frank X. Gilg

Frank X. Gilg, 57, an executive assistant in the Boiler Division of the Babcock & Wilcox Co., died suddenly on January 26th after a heart attack suffered at his home in Bronxville, N. Y. He had recently been hospitalized in San Francisco after a heart attack in November, and had only been able to return to his home about two weeks ago.

Born on June 6, 1900, in Elizabeth, N. J., Mr. Gilg joined B&W in 1922 as a draftsman at the company's former Bayonne, N. J., plant. He was subsequently appointed design engineer in the research department before being transferred to the New York service department in 1930. He was made a staff engineer in 1945, and an application engineer in 1948. In 1953, he was appointed executive assistant in the Boiler Division.

Mr. Gilg received his early education at St. Michael's school and Continental School No. 3 in Elizabeth, and at the Newark, N. J., Technical School. After joining B&W, he attended Cooper Union at night, receiving a B.S. degree in 1923, and a M.E. degree three years later.

Widely known in the boiler industry, Mr. Gilg also was a member of several committees of the American Boiler and Affiliated Industries, the American Society for Testing Materials, the American Standards Assn., the International Institute of Welding and the Uniform Boiler and Pressure Vessel Laws Society.

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AGAIN FOR THE THIRD STRAIGHT YEAR "EUTECTIC" TECHNICAL REPRESENTATIVES WIN HIGHEST AWARDS FOR THE WELDING INDUSTRY

These Distinguished Salesman's Awards are presented by the National Sales Executives Club only to those men who have shown "outstanding ability to render valuable **service** to industry." The winners for the welding industry . . . "Eutectic" Technical Representatives Darrel Lent of U.S.A. and Claude Joyal of Canada . . . are but two of 350 "Eutectic" Technical Representatives who bring their know how and experience into shops and plants throughout the United States and Canada!

Factory trained by "Eutectic", whose pioneering in Low Temperature Welding Alloys and Techniques have made metal joining history, these Technical Representatives used their specialized knowledge to help solve production, maintenance and salvage welding problems in over 100,000 shops and plants in 1957!

Darrel Lent

Claude Joyal

Darrel Lent and Claude Joyal exemplify the professional stature of all "Eutectic" Technical Representatives. Their willingness to render **service** . . . to help the weldor and welding user with practical, money, labor and time saving suggestions . . . have given "Eutectic" Technical Representatives top honors in the Distinguished Salesman's Awards for the welding industry.

If you use welding . . . the most valuable asset in your shop can be the obligation-free **service** brought to you by your "Eutectic" Technical Representative . . . a service available to every user of "Eutectic" products. Call him today!

Eutectic Welding Alloys Corporation is the inventor, patentee, and only manufacturer of Eutectic "Low Temperature Welding Alloys",® which minimize or completely eliminate the troublesome warping, distortion, stress and embrittlement caused by conventional high heat welding materials.

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Phoenix	ALpine 3-0900
St. Louis	GEneva 6-4644
Montreal	RAymond 1-4930, 1-4939
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For more details, circle No. 31 on Reader Information Card

NEW LITERATURE

Rust Preventative

The Sealube Co., Wakefield, Mass., is offering a 4-page folder which discusses "how zinc-rich coatings stops rust and rust creepage." Included is technical information on product description, theory, practice, instructions, surface preparation and uses. According to Sealube, the product, called Z.R.C., has proved of value for touching up galvanized surfaces that have been welded or the surface otherwise impaired. Z.R.C. is said to be flexible and to combine readily with the existant galvanizing to produce a complete bond.

For your free copy, circle No. 32 on Reader Information Card.

"Weld-It"

The automotive industry is represented in a 4-page issue, No. 5710, of "Weld-It," published by the Taylor-Winfield Corp., Warren, Ohio. One article discusses how one automobile manufacturer makes use of two machines for butt-projection welding. Another article depicts some of the applications an automobile manufacturer employs with over 200 resistance-welding machines, all Taylor-Winfield models.

For your free copy, circle No. 33 on Reader Information Card.

Abrasive Protection

"Kenplate Tungsten Carbide Surfacing" is the title of a new bulletin issued by Kennametal Inc., Latrobe, Pa. The 4-page bulletin describes a new product introduced by Kennametal, its uses in protecting metal parts against abrasion and wear, and application methods. Kenplate consists of small hexagonal carbide buttons assembled on a flexible backing material for bonding on metal surfaces.

For your free copy, circle No. 34 on Reader Information Card.

Brazing Control

A new one-page 8½ x 11 two-color engineering data sheet (Number 14) describing Nidrobraz "stop-off" materials for control of brazing-alloy flow is now available from Stainless Processing Division, Wall Colmonoy Corporation, 19345 John R. St., Detroit 3, Mich.

Described in the new data sheet are "green stop-off," "white stop-off" and Nicrobraz "stop-off" mixtures. For each is indicated its function, use, properties and solvent. A paragraph in each section is devoted to a brief discussion of application techniques. Recommendations for removal of each stop-off material following brazing are also included.

For your free copy, circle No. 35 on Reader Information Card.

X-Ray Information Booklet

A new 16-page booklet titled "Questions and Answers on X-ray Diffraction, Diffractometry and Spectrography" is available from the Instruments Division, Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Seventy-one questions and answers cover points most frequently raised by people who have attended Norelco X-ray diffraction schools during the past ten years. Data deal with camera, diffractometer and spectrograph equipment and techniques.

The booklet explains specimen preparation and describes fields of application for the three basic X-ray analysis methods. It also discusses the selection of analyzing crystals and calibration of the spectrograph for quantitative work on elements.

For your free copy, circle No. 37 on Reader Information Card.

Metalworking Bulletin

Beginning with the March 1958 issue, the *Linde Metalworking Bulletin*, published bi-monthly by Linde Co., Division of Union Carbide Corp., will have a new look: 12 pages in two colors. The *Bulletin*, designed to demonstrate the many industrial advantages of modern electric welding and cutting processes, contains an average of six short, concise articles in each issue. The easy-to-read publication features interesting, cost-and-time saving applications of both manual and mechanized electric welding, spot welding and cutting processes. If you would like to receive this publication free of charge, write on company letterhead to: Metalworking Bulletin, Rm. 2840, 420 Lexington Ave., New York 17, N. Y.

Steel Data

A technical data card is now available from the Tubular Products Division of the Babcock & Wilcox Co., Beaver Falls, Pa. This card, TDC-115D, furnishes data taken from the new edition of the Steel Tubular Products Section of the *AISI Steel Products Manual*. The data card covers the dimensional tolerances, both cold-drawn and hot-finished, of round seamless carbon and alloy-steel mechanical tubing in various conditions of heat treatment.

For your free copy, circle No. 36 on Reader Information Card.

Positioning and Tooling

Airline Welding Sales, Inc., 730 N. Prairie Ave., Hawthorne, Calif., has issued four-page Bulletin No. 5-12-57 which contains basic information on the welding fixtures and welding tooling developed by the West Coast firm. Included are data on circumferential welding machines, longitudinal welding positioners and weld roll-planishing machines.

For your free copy, circle No. 38 on Reader Information Card.

Brazing News

Issue No. 78 of *Brazing News* is available from Handy & Harman, 82 Fulton St., New York 38, N. Y. The four-page bulletin describes silver-brazing methods in such applications as belt buckles, clutches, power saws, bowling pin spotters, radar equipment, etc.

For your free copy, circle No. 39 on Reader Information Card.

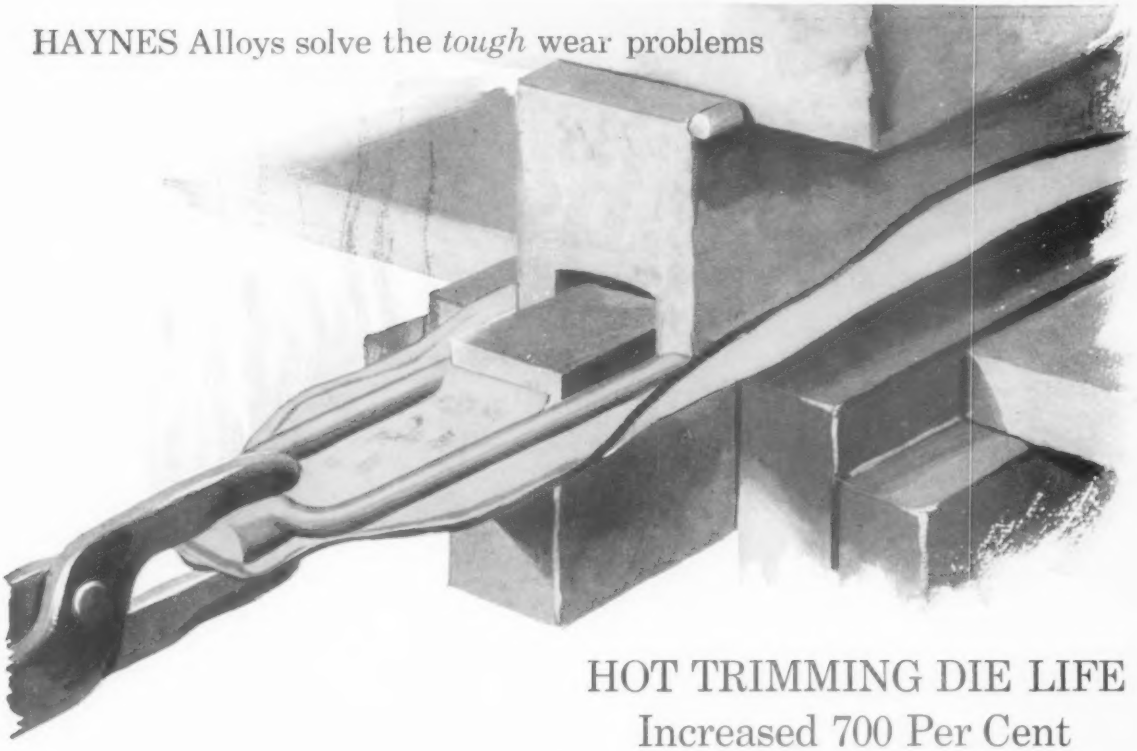
Photodrawings

According to Eastman Kodak Co., Rochester 4, N. Y., a 12-page illustrated booklet has been prepared entitled "Photodrawings" in answer to the requests of draftsmen, engineers and industry production men who have expressed great interest in the procedure. Previously, such requests were answered by mimeographed information and drawings.

The booklet discusses two different methods of preparing photodrawings for use in various areas of industry including assembly, inspection and engineering.

Included are sections on making the picture negative, equipment and materials needed, making the master photodrawing, direct process reproduction, halftone methods, continuous tone

HAYNES Alloys solve the *tough* wear problems



HOT TRIMMING DIE LIFE
Increased 700 Per Cent

HAYNES hard-facing alloys resist the sudden shock of impact and the softening effects of heat . . . two characteristics that make them unusually successful in extending the service life of hot-working equipment. In one plant, hot-trimming dies hard-faced with a HAYNES cobalt-base alloy removed the flash from 25,000 parts before they had to be reconditioned. This was a 700 per cent increase in service life over unprotected dies. In this instance the parts were heated to 2000 deg. F just prior to the trimming operation.

If you have a problem involving a combination of heat and impact, straight abrasion, or corrosion, you will find that there is a HAYNES hard-facing alloy that can solve it . . . economically. The hard-facing deposit will increase the service life of the part and, because of its superior wearing qualities, permit you to use a less expensive base material.

Write for literature or call one of our sales offices. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, Kokomo, Indiana. Sales offices in Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, San Francisco.

This trimmer die, being touched up with a HAYNES nickel-base alloy, has trimmed over 20,000 parts. The hard-facing alloy is tough, machinable, and can be applied to all common die steels by the metallic-arc process.

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ALLOYS

HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

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For more details, circle No. 41 on Reader Information Card

methods, composite methods, blueprint reproduction and lithographic reproduction.

For your free copy, circle No. 40 on Reader Information Card.

Welding Abrasives

Abrasive Products for the Welding Trade—12-page brochure, is now available from the Carborundum Co., Niagara Falls, N. Y.

Designed as a source book for abrasive supplies and accessories manufactured by the company for the welding trade, the publication contains specifications, pictures and suggested applications for MX and Carboflex depressed center and cut-off wheels, Aloxite vitrified and resinoid grinding wheels, MX and resin sander disks, abrasive belts, Aloxite metal cloth and MX mounted wheels.

For your free copy, circle No. 42 on Reader Information Card.

Resistance-Welding Data

New Bulletin SP-7A, The Taylor-Winfield Corp., Warren, Ohio, contains technical data on seam welding low-carbon and stainless steels. Charts, macrophotographs of welds, production photos and technical descriptions cover this specialized welding from material preparation to weld testing.

The 16-page seam welding bulletin contains specific details on welding techniques and production speeds, use of interrupted and continuous current on low-carbon steel, welding dissimilar thicknesses of low-carbon steel, use of interrupted current on stainless steels, mash-seam welding techniques and roll-spot welding calculations.

For your free copy, circle No. 43 on Reader Information Card.

Welding Engineering Services

NADCO Engineering Co., 3633 Brownsville Rd., Pittsburgh 27, Pa., announces the availability of an 8-page booklet describing some of their services as welding engineering consultants. According to NADCO, their staff includes welding engineers, mechanical and structural engineers, metallurgists, welding engineering consultants and radiography technicians.

For your free copy, circle No. 46 on Reader Information Card.

Surfacing

Articles appearing in the Fall 1957 issue of *Fusion Facts*, published by Stoody Co., Whittier, Calif., treat the use of surfacing in such applications as rock products, dam construction and mining. The feature article, entitled "Uranium Discovery on an Indian Reservation," concerns the application of Stoody 100 on shovel teeth and buckets which are used in extracting the ore.

For your free copy, circle No. 44 on Reader Information Card.

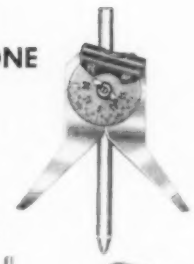
Surfacing Data

A new 8½ x 11 five-page illustrated two-color engineering data sheet (No. 32) describing instructions and procedures for hard surfacing farm implements is now available from Wall Colmonoy Corp., 19345 John R. St., Detroit 3, Mich.

This new data sheet gives detailed instructions for applying hard-surfacing alloys to plowshares, moldboards, landside plates, lister shares and similar parts, as well as various knives, cultivator spikes, spring teeth, mill hammers, root cutters, disks, rasp bars, cutter bars and hand tools.

For your free copy, circle No. 45 on Reader Information Card.

Really FIVE TOOLS in ONE



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Weighs only 9 ozs. Pocket size.

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BOUND VOLUMES OF 1957 JOURNAL NOW AVAILABLE

Bound Volumes of THE WELDING JOURNAL for the year 1957 are available in black imitation leather covers, together with a comprehensive subject and authors index. Price $15, including postage.

This volume, comprising a total of 1260 pages in the JOURNAL and an additional 552 pages in the *Welding Research Supplement*, represents a veritable encyclopedia of information in the Welding field. Copies may be ordered through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

3 BIG REASONS WHY SO MANY WELDERS HAVE SWITCHED TO HI-AMP® ELECTRODE HOLDERS

1- Wrap around Glass Fibre Tip Insulation—30% more heat resistant than any other make.

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Better Welding...

these manufacturers know how...
by AUTOMATIC arc control.

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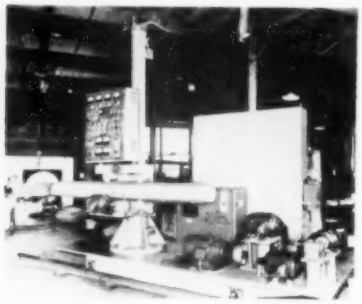
For more details, circle No. 49 on Reader Information Card

NEW PRODUCTS

Twin Head Manipulator

The C. B. Herrick Manufacturing Corp., 2000 Center St., Cleveland 13, Ohio, has announced a new model heavy-duty twin-head ram-type manipulator. Complete control of all ram machine movements plus independent and/or simultaneous control of both heads is a feature. Arc start and stop, wire inch up and down, current raise and lower, flux feed and shut off are included.



According to the manufacturer, ram travel is electronically controlled with speed range of 5 to 100 ipm. Carriage travel has three forward speed ranges plus 300 ipm rapid traverse, all electronically controlled. Cross adjustment of both heads is motorized with range of 0" to 48" arc to arc.

For more details, circle No. 50 on Reader Information Card.

A-C Arc Welder

A new industrial a-c transformer-type arc welder of the "diverter path" design is being announced by Hobart Brothers Co., Troy, Ohio.

The manufacturer reports that the "diverter path" control for adjustment

of welding current provides five steps of coarse adjustment (range settings 1-2-3-4-5), with a rheostat for fine adjustment in each range. Extra secondary winding supplies current to control rectifier, which is of standard selenium type—35 v dc for safe, low voltage remote control. No high voltage appears across any control coils, eliminating possibility of insulation breakdown or high voltage appearing under the rheostat handle. This type control is said to eliminate the need for moving parts; core and coils are anchored in place for quiet operation and less maintenance.

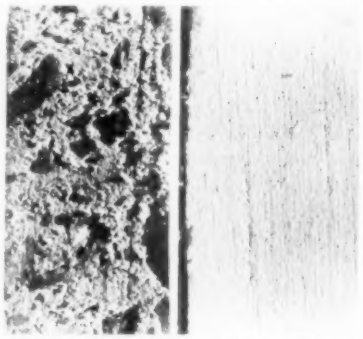
Model TD-316-S is rated 300 amp at 40 v ac with a welding range of 35 to 375 amp. Model TD-416-S is rated 400 amp at 40 v ac with a welding range of 35 to 500 amp. Model TD-516-S is rated 500 amp at 40 v ac with a welding range of 35 to 625 amp.

For more details, circle No. 51 on Reader Information Card.

Acetylene Cylinder Filler

An improvement in their patented calcium-silicate acetylene cylinder filler has increased its porosity to 92%, Linde Co., Division of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y., has just revealed.

The new filler is reported to be lighter than Linde's former standard filler,



Charcoal Monolithic Calcium Silicate

which had 82% porosity. Prest-O-Lite acetylene cylinders now weigh as much as 28.6% less than cylinders containing old-style charcoal monolithic filler.

Linde reports that the improved filler is the most important gas transportation development in 50 years. Besides improved porosity, the manufacturer claims it is stronger, longer lasting, will not deteriorate and can be charged and discharged faster than any other filler.

The calcium-silicate filler is formed inside the cylinder, producing a highly porous (92% void) mass which conforms to the cylinder shape, has virtually uniform density and will not settle or crack in normal service.

For more details, circle No. 52 on Reader Information Card.

Oxyacetylene Welding Torch

Harris Calorific Co., 5501 Cass Ave., Cleveland, Ohio, has developed a newly designed welding torch, designated the No. 43.

The No. 43 torch is said to be well adapted to construction work and general use in industry for welding and cutting applications. It is a universal

pressure torch, and will operate on high, medium or low pressures. A wide range of styles and sizes of tips are available.

For more details, circle No. 53 on Reader Information Card.

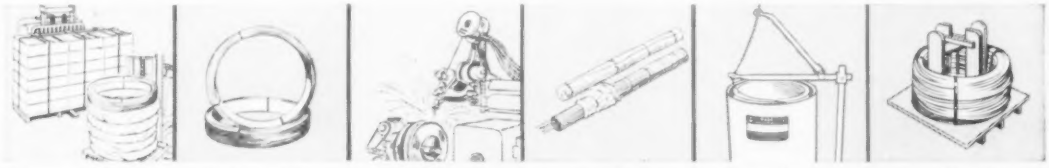
Radiography Unit

A new portable, lightweight industrial radiography unit (MG 100), which reportedly provides sharp radiographic detail and exceptional penetrating power, has been announced by the Instruments Division, Philips Electronics, Inc., 750

PAGE Welding Wire

The RIGHT Packaging for the RIGHT Wire

• When you choose PAGE Welding Wire, you are assured of getting the exact wire for your application—and receiving it packaged to provide maximum protection and convenience. PAGE has developed a packaging program to cover practically every requirement in the broad fields of automatic, semi-automatic and manual welding. Coils, reels, bundles, cartons, Leverpaks, Payoffpaks, Payoffpallets... PAGE has them all! Look to PAGE for the *right* packaging of the *right* wire.



Wrapped Coils—Coils in Cartons | Welding Wire in Coils | Handy Reels | Gas Rod Packing | Payoffpaks and Leverpaks | Payoffpallets

This Chart Shows How PAGE Offers The Exact Packaging You Want

PACKAGING ↓ / PAGE WIRE for →	Gas-shielded consumable electrodes: Automatic Welding	Gas-shielded consumable electrodes: Semi-Automatic Welding	Filler wire for automatic or manual Inert Gas Welding	Submerged Arc Welding	Straight and cut lengths Bare wire: Manual Electric Welding	Straight and cut lengths Bare wire: Oxy-acetylene Welding
25-lb. or 60-lb. coils wrapped in waterproof paper, steel-strapped, single or palletized.	✓	✓	✓	✓		
25-lb. or 60-lb. coils in individual cartons, single or palletized.	✓	✓	✓	✓		
120 or 180 lb. (22"/24" I.D.) coils, paper-and-burlap wrapped, or in cartons, palletized.	✓			✓		
Special coil sizes (on application).	✓	✓	✓	✓		
25-lb. reels (spools) in carton to fit all standard machines; single or palletized.	✓	✓	✓	✓		
Leverpaks, 15" dia., 25-lb. coils (12" I.D.x2½" wide); Leverpaks, 17" dia. 50/60-lb. coils (12" I.D.x4" wide).	✓	✓	✓	✓		
Payoffpaks: 20" dia. size holds up to 500 lbs.; 23" dia. size holds up to 700 lbs.	✓	✓		✓		
Payoffpallets, holding 900-1200 lbs. of wire (3/16" to 3/8" sizes, incl.) coiled around pedestal on a wooden pallet.				✓		
Paper-and-burlap wrapped bundles, containing 50 lbs. of rods in 36" lengths.			✓			✓
Fibreboard cartons, containing 10 lbs. of rods in 36" lengths; single or boxed. 50# and over.			✓			✓
Burlap-wrapped 50-lb. bundles of bare wire electrodes in 14" and 18" lengths.			✓		✓	

33 DIFFERENT ANALYSES

PAGE covers the field of applications with *33 different analyses:* heavy automatic submerged arc..light manual submerged..inert gas manual...automatic, tungsten or metal arc, and oxy-acetylene gas welding.

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PAGE welding wire and rods are available from your nearby PAGE Distributor or PAGE warehouse stocks (*see list at right*).

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- **Booklet DH-1277** PAGE Gas Welding Rods
- **Welding Rod Comparison Chart**

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S. Fulton Ave., Mount Vernon, N. Y.

It is said to be powerful enough for tasks involving steel welds and opaque materials such as aluminum, magnesium, rubber, plastics, porcelain, glass and food products.

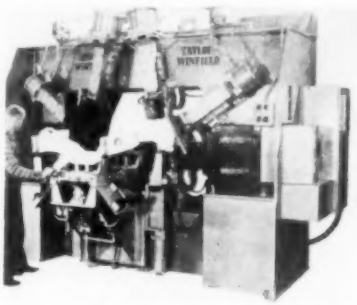
According to the manufacturer, the MG 100 weighs 45 lb and is housed in an enameled steel case measuring 16 × 12 in. × 6 ¾ in. It is connected to the tubehead through a flexible multiconductor cable. Kilovoltage regulation is stepless and is continuously variable from 30 to 100 kvp.

For more details, circle No. 56 on Reader Information Card.

Projection Welder

A special projection welder built by the Taylor-Winfield Corp., Warren, Ohio, reportedly welds four brackets to automobile frame front cross members at a rate of up to 300 assemblies per hour.

Two operators load the cross member on a walking-beam transfer shuttle that extends from the front to rear of the



welder. Four brackets are loaded in the machine's upper welding heads. The 800-kva welder joints the brackets to the cross member and automatically unloads the assembly onto an adjacent conveyor.

The Taylor-Winfield welder is said to locate the brackets on the rough stamping to a tolerance of 0.020 in. Each loading, welding and unloading cycle is completed in 12 sec.

For more details, circle No. 57 on Reader Information Card.

Carbon-Air Cutting

Two new heavy-duty models of the Arcair torch for metal removal have been developed and are now available from the Arcair Co., P. O. Box 31, Lancaster, Ohio. The manufacturer reports that the new torches can be used wherever intricate contouring (Model G-55) or large volume (Model M-6) metal removal is required, with advantage to foundry users confronted with the problems of riser stub and flash removal, etc.

According to Aircair, the Model G-55 torch features air jets on both sides of the electrode for increased maneuverability. But it is for heavy-duty service, using ½- and ⅝-in. electrodes

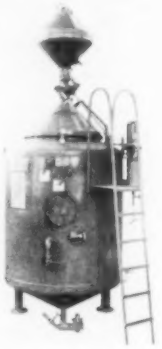
only. Reportedly an improvement on its predecessor G-53 model, the G-55 now has heads insulated with silicone glass laminate, and the air supply can be controlled by rotating the heads.

The Model M-6 torch is designed for heavy-duty foundry-type applications, such as pad washing. Built basically for ⅜-in. electrodes, it is nevertheless available in ½ and ⅝ in. sizes. Electrode angle is permanently fixed, and ample contact area is said to assure high current capacity. A heat shield protects the operator's hand, and the air control is a push-button.

For more details, circle No. 59 on Reader Information Card.

Acetylene Generator

The Oxweld MP-11 acetylene generator with a newly developed automatic signal system has been introduced by



Linde Co., Division of Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y. With a reported carbide capacity of 500 lb, the MP-11 will produce 1000 cu ft of medium-pressure acetylene per hour. Delivery rates of up to 2000 cu ft of acetylene per hour are said to be obtainable over shorter intermittent operating periods.

The new automatic signal system consists of a howler and indicator lights that provide both audible and visual warning if minimum carbide supply, water level or water temperature should deviate from normal. According to Linde, three independent circuits make

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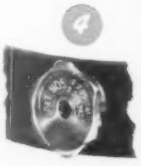
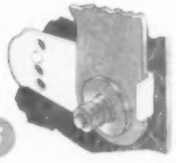


Revolutionary, light, durable material with entire mechanism enclosed in fibre tube insulating it from head of wearer. Right or left turning to adjust size . . . remains positive.

4-POSITION ADJUSTABLE HELMET STOP 5



Positions helmet for overhead and vertical welding. Positive stop, easily adjustable to any of 4 positions without tools. Allows normal raising of helmet on friction joints.

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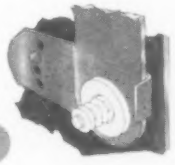

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up the signal system so that the generator can be equipped with any combination of audible or visual signals for these three conditions. The unique signal system notifies the operator of abnormal conditions even if he is a considerable distance from the generator building.

For more details, circle No. 61 on Reader Information Card.

A-C/D-C Welder

A new combination a-c transformer/d-c rectifier arc welder with provisions provided for inert-gas welding is being announced by Hobart Brothers Co., Troy, Ohio.

Welding with either ac or dc (straight or reverse polarity) is accomplished by shifting a selector switch. It also has a magnetic line switch and removable rheostat for remote control.

The manufacturer reports that a current overload device protects both transformer and rectifier, while a thermostat provides an additional safeguard for the rectifier. Both of these devices open the primary contactor, thus assuring full overload protection.

Model AD-264-8 is rated 200 amp at 40 v and has a welding range of 12 to 330 amp ac, 12 to 360 amp dc. Model AD-364-8 is rated 300 amp at 40 v and has a welding range of 12 to 420 amp ac, 12 to 400 amp dc.

For more details, circle No. 62 on Reader Information Card.

Bronze Brazing Rod

Available in 5 diameters ($\frac{1}{16}$ to $\frac{1}{4}$ in.), Ambraze No. 411 low-fuming bronze brazing rod is recommended by American Brazing Alloys Co. P. O. Box 11, Pelham, N. Y., for general-purpose, all-around welding and brazing work.

Its low melting point (1575° F) reportedly allows free flow and produces a tough, yet ductile, weld deposit of very high (70,000 psi) tensile strength. Ambraze No. 411 is said to meet all applicable Government, ASTM and AWS standards and has a composition of RCuZn-C.

For more details, circle No. 64 on Reader Information Card.

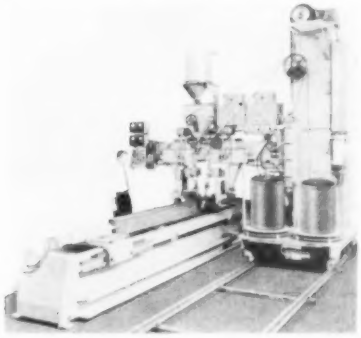
Torch Lighter

The Thermacote Co. of Pasadena, Calif., announces the introduction of a battery-operated oxyacetylene torch lighter which reportedly makes quick and easy placement and release on any unpainted metal surface. The new lighter, known as "Torchie," is said to eliminate flint and open flame lighters and to provide an instant positive light.

For more details, circle No. 65 on Reader Information Card.

Submerged-Arc Welder

An automated submerged twin-arc welding machine that reportedly performs controlled welding operations on both sides of extra large production parts is now available from Expert Welding Machine Co., 17144 Mt. Elliott Ave., Detroit 12, Mich.



The Expert automated welding machine occupies a floor space about 15 x 15 ft and is 13 ft high. The carriage is driven by a potentiometer controlled d-c motor. Maximum up and down beam travel is 18 in.

For more details, circle No. 66 on Reader Information Card.

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After spraying, the overlay is fused to the base metal.

Rocker arms being sprayed with the Spraywelder.

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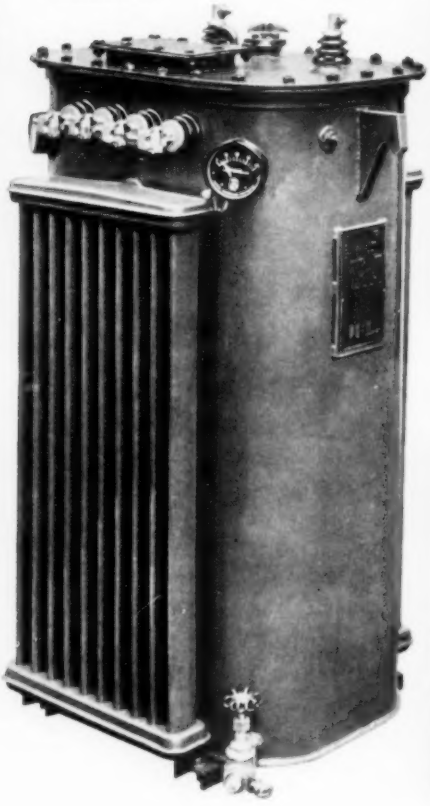
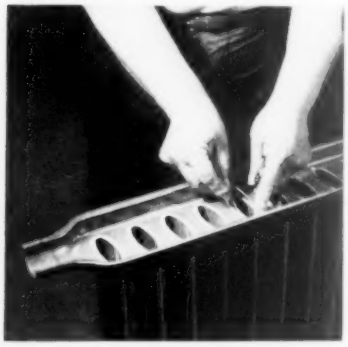
Operator places oval carbon-steel tubes in slots and presses them into headers.

Completed radiator attached to transformer.

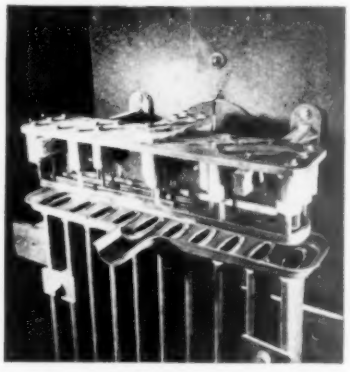


Pre-formed ring of EASY-FLO 35 is placed in joint area.



HANDY FLUX is applied with syringe.

Holders position assembly in induction rig, induction coil is lowered, heat applied for 90 seconds; afterward joints are sandblasted to remove flux which could contaminate transformer oil.



How EASY-FLO Brazing Helps Shaw-Perkins Simplify Techniques, Cut Production Costs

Changing to silver brazing with EASY-FLO 35 brought many benefits to Shaw-Perkins Manufacturing Company, manufacturer of radiators for liquid-cooled transformers. The radiators are made up of banks of steel tubes assembled to inlet and outlet headers. Hot oil from the transformer enters at the top of the radiator and flows downward, returning to the transformer at a lower temperature.

Before Handy & Harman silver alloy brazing entered the production picture, the tubes were arc-welded and gas-welded to the headers. Now, rings of EASY-FLO 35 are preplaced and induction-brazed with results that *any* manufacturer would be happy to talk about: rework is almost nil (arc-welded joints had often failed to pass inspection), production space has been reduced (two silver brazers now do the work of six arc welders in a simplified assembly pattern), lower silver-brazing temperature minimizes possibility of unit failure in service due to metal fatigue. Radiators *look* better, have smoother fillets.

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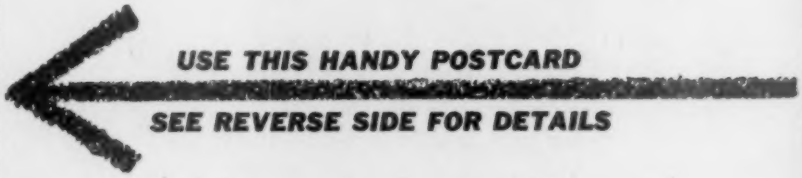

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SUPPLEMENT TO THE WELDING JOURNAL, MARCH, 1958

ULTRASONIC WELDING OF STRUCTURAL ALUMINUM ALLOYS

Program undertaken to explore the ultrasonic weldability of aircraft structural aluminum alloys and to investigate the effect of resistance heating as an auxiliary to such vibratory welding

BY J. BYRON JONES AND FLORENCE R. MEYER

Introduction and Background

This program was undertaken to explore the ultrasonic weldability of aircraft structural aluminum alloys and to investigate the effect of resistance heating as an auxiliary to such vibratory welding. Throughout this report, ultrasonics is defined as high-frequency and/or high-intensity elastic vibration.

Background of Ultrasonic Welding

Ultrasonic welding is a process for joining metals and metal alloys without the aid of solders, fluxes or filler metals and usually without externally-applied heat. The metals to be joined are clamped at low static pressure between welding tips or sonotrodes, and ultrasonic energy is introduced for a brief interval, usually 1-3 sec. A strong metallurgical bond is produced without the significant external deformation that characterizes pressure welding and without the cast-metal zones associated with resistance welding.

Development of ultrasonic welding has been pursued for about seven years. The work stemmed from experimentation for the Bureau of Aeronautics[1-7] devoted to the application of ultrasonics to standard aircraft spot welding with the intent of improving spot-weld quality and of simplifying the cleaning of aircraft materials prior to fusion spot welding. This effort produced evidence of effects at the interface between the members being welded; in particular, the interfacial electrical resistance of weldment components could be abruptly reduced by short bursts of ultrasonic energy to achieve resistance levels characteristic of sheets cleaned by expensive washing and etching methods. Occasionally, a pair of specimens would stick together after the application of ultrasonic energy alone, without applied electric welding current. Examination of the faying surfaces of such specimens indicated slight surface abrasion.

In further work, development and extension of ultrasonic welding *per se* was carried out. Initially soft aluminum foil specimens 0.005 to 0.010 in. thick were used, and equipment was similar to that used in the early experiments with resistance welding.[3] The first successful "welds" of soft aluminum foil coupons were characterized by tensile-shear strengths of but a few grams; when tested, these so-called welds would always fracture in the bond zone. As the work progressed and equipment was altered and refined, bond strengths improved, and it became possible to pull small nuggets out of soft aluminum foil in these thin gages.

Subsequent developments in ultrasonic-welding equipment and techniques have significantly extended the range of weldable materials and material thicknesses. Successful welds have been produced in a variety of aluminum alloys and stainless steels, in nickel, brass, and copper, and in some of the more exotic metals, such as molybdenum, titanium alloys, zirconium alloys and Inconel. Dissimilar-metal combinations are also readily weldable.

Typical ultrasonic spot-type welds are characterized by disturbance and disruption of the interfacial plane; essentially complete solid-phase metallurgical structure between the two sheets can be achieved. An important aspect of vibratory welding is the low power level necessary to accomplish such welds in aluminum in comparison with power requirements of resistance spot-welding equipment.

Ultrasonic welding, although a solid-phase metallurgical phenomenon, at least on any ordinary microscopic scale, differs from ordinary pressure welding in that the welding is accomplished (a) in shorter times, (b) with inconsequential deformation (<5% instead of 60-80%), and (c) with low applied static force. Ultrasonic welding achieves the same order of weld strength as does pressure welding without some of the disadvantages that are reputed to be typical of pressure welding, partic-

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ularly the need for exceedingly meticulous cleaning prior to and the excessive deformation after joining. Spot-type welds can be made to overlap, and criticality of edge distance and row spacing is believed to be less than for resistance spot welds.

In addition to basic ultrasonic spot-type welding equipment and its adaptations for welding configurations other than the sheet type, equipment has been developed to achieve continuous seam-type welds.

Scope of the Problem

The application of ultrasonic or vibratory welding to the joining of aircraft materials necessitated study of physical equipment variables, such as transducer-coupling system design, sonotrode tip radius, etc., as well as study of the power, force, and time factors associated with the actual welding operation. In particular, since it had been previously observed that auxiliary heating of the weldment could extend the effective range of this new welding method to heavier metal members, a reasonably comprehensive experimental study of "warm welding" was carried out.

The specific objectives of the program were as follows:

1. To design and construct transducers and transducer-coupling arrays that could be used without auxiliary heat or in conjunction with resistance heating to make ultrasonic welds.

2. To investigate the ultrasonic weldability of structural aluminum alloys, selected from bare and Alclad 2024-T3 and bare and Alclad 7075-T6, in sheet-to-sheet and sheet-to-extruded section configurations in thicknesses of 0.032 in. and heavier.

3. To investigate the welding parameters of applied static force, r-f driving power, ultrasonic pulse time and preheat temperature in order to arrive at operable welding conditions.

4. To evaluate the welds obtained by means of static shear-strength tests, supplemented by metallographic studies as required.

5. To investigate ultrasonic seam welding and area welding in the above-mentioned structural aluminum alloys.

In furtherance of these objectives, revisions and refinements were made in the ultrasonic-welding equipment throughout the program; as a measure of improvement, comprehensive data were obtained on the room-temperature and resistance-heated ultrasonic welding of 1100-H14 aluminum in gages ranging from 0.032 to 0.081 in. Satisfactory machine settings were established for room-temperature and warm welding of 2024-T3 bare aluminum alloy in gages from 0.032 to 0.064 in. and in 2024-T3 Alclad aluminum alloy in thicknesses of 0.020 to 0.064 in.; spot checks with 7075-T6 Alclad aluminum alloy indicated it to be as readily weldable as 2024-T3 Alclad. In addition, exploratory studies were made in the seam-welding of 0.020-, 0.025-, and 0.032-in. 2024-T3 Alclad sheet material.

Development of Ultrasonic-Welding Equipment

Extension of existing ultrasonic-welding equipment and techniques to the joining of structural-aluminum aircraft components necessitated further development of basic ultrasonic spot welding and continuous-seam welding arrays, and efforts were extended in this direction during the program.

An ultrasonic-welding system consists basically of an electronic device for generating alternating-current power at the desired frequency; a welding array for converting the high-frequency a-c power into elastic vibratory energy and for delivering this power into the weld zone; and appropriate auxiliary equipment for applying static load to the workpieces and for controlling the duration of the ultrasonic pulse in spot-type welding or the rate of continuous welding.

Laboratory-Type Ultrasonic Spot Welder

Spot-type vibratory welding at room temperature was carried out by means of the standard laboratory unit shown in Fig. 1. The welding unit in the center of the assembly consisted of a nominal 15-kc magnetostrictive nickel stack to convert a-c power into mechanical vibratory energy, a metal coupler system to transmit this energy into the weld zone and a reflector anvil to minimize transmission of the energy through and beyond the workpieces.

The geometry of the system is shown in Fig. 2. The ultrasonic sonotrode was a metal rod with the upper end restrained in a clamping mass; at its lower end was the welding tip, made of high-speed steel usually contoured to a spherical radius of 3 in. The nickel-stack transducer was bonded to a wedge-shaped coupler which in turn was brazed at right angles to the rod, thus driving the rod laterally and introducing primarily shear vibration into the weld zone. This array was later modified to provide a heavier-duty system that would permit the delivery of substantially greater power into the weld zone.

Practical transducer-coupling systems requisite for ultrasonic welding must be force insensitive; that is, under conditions of different or transient clamping forces on the weldment, the resonant frequency of the system must not change. Furthermore, it is implicit that the system be so designed that there are no energy sinks other than the weld zone of the workpieces. The concept of force-insensitive transducer-coupling systems is not old. The array shown in Figs. 1 and 2 is essentially force insensitive.

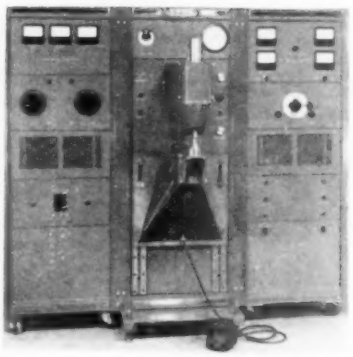


Fig. 1 Ultrasonic spot-type welding equipment

There are additional problems associated with a system that must handle substantial power levels. The various joints in the system must be sound and must not fail in fatigue. A removable tip is essential for ordinary practicability, and its attachment must be such that energy will not be lost at the junction between the tip and the coupling member to which it is attached. The junction between the lateral drive and the cylindrical reed must be designed to achieve an impedance match between the longitudinal waves in the lateral member and the flexural waves in the reed member. Furthermore, data obtained during earlier investigations indicated a sensitivity of ultrasonic weld quality to the material and configuration of the reflector anvil against which ultrasonic welds are made.

The laboratory spot welder shown in Fig. 1 included a hydraulic system for applying static load to the workpieces, an electronic timer for controlling ultrasonic pulse length and suitable air blowers to maintain operating temperatures within reasonable limits. The welding array was powered by a 2000-watt electronic generator, shown in Fig.

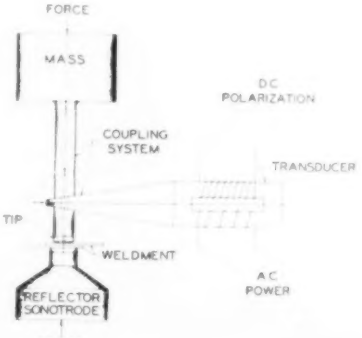
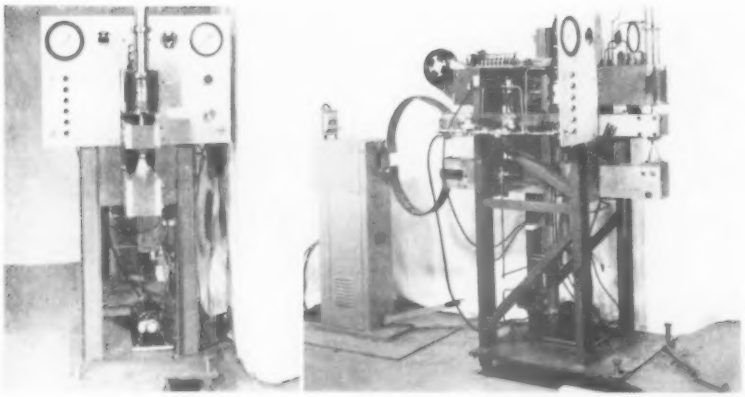


Fig. 2 Diagram of ultrasonic transducer-coupling system



a. Front View b. Side View

Fig. 3 Ultrasonic spot-type welder combined with resistance-heating source

1 with the power-supply rack to the left and the power amplifiers to the right of the welding unit.

Resistance-Heated Ultrasonic Spot-Welding Array

For elevated-temperature investigations, standard ultrasonic spot-type equipment was rigged to combine with a resistance-heating source (10-kva, 5-kw-spot welder) as illustrated in Fig. 3 and in the schematic drawing of Fig. 4.

It will be observed in Fig. 4 that two heavy aluminum bus bars E-E were rigidly mounted through the structural frame of the standard laboratory welder, in substitute for the lower reflector sonotrode support shown in Fig. 2. The conventional reed-coupling array on its supporting beam was revised only to incorporate the rather sharply-tapered reed-end tip to permit access by the current-conducting cone surrounding the tip (B of Fig. 4). The cone was carried on a second, lighter pair of aluminum bus bars E'-E'. This upper bus-bar system was pivoted and activated by means of an air cylinder, independently of the hydraulic system which supplied clamping force during the welding cycle.

Initially, it was intended that resistance heat would be introduced into the weldment through an annulus around the tip of the reed of the transducer-coupling array. However, early experimentation with this system indicated that it should be more desirable for the heating current to enter through the tip itself. Using the mechanically-replaceable tip assembly shown in Fig. 5, the current was delivered through a very small annulus of the active tip.

Operation was accomplished essentially in the following sequence: (1) the air cylinder applied force to the heating cone of Fig. 5 in contact with the clamping nut; (2) simultaneously, hydraulic force was applied to the transducer-coupling-reed system; (3) heating current from the resistance spot welder was introduced for a brief interval; (4) the air cylinder removed clamping force from the heating cone and clamping nut, and elastic vibratory energy was simultaneously introduced through the welding tip; (5) ultrasonic energy was cut off and hydraulic clamping force on the sonotrode relieved.

Sequential operation for various phases of the welding cycle was incorporated in the system. Duration of applied clamping force, duration of applied current (heat), initiation and duration of ultrasonic application to the workpieces (either during or after the heating cycle) were completely interlocked.

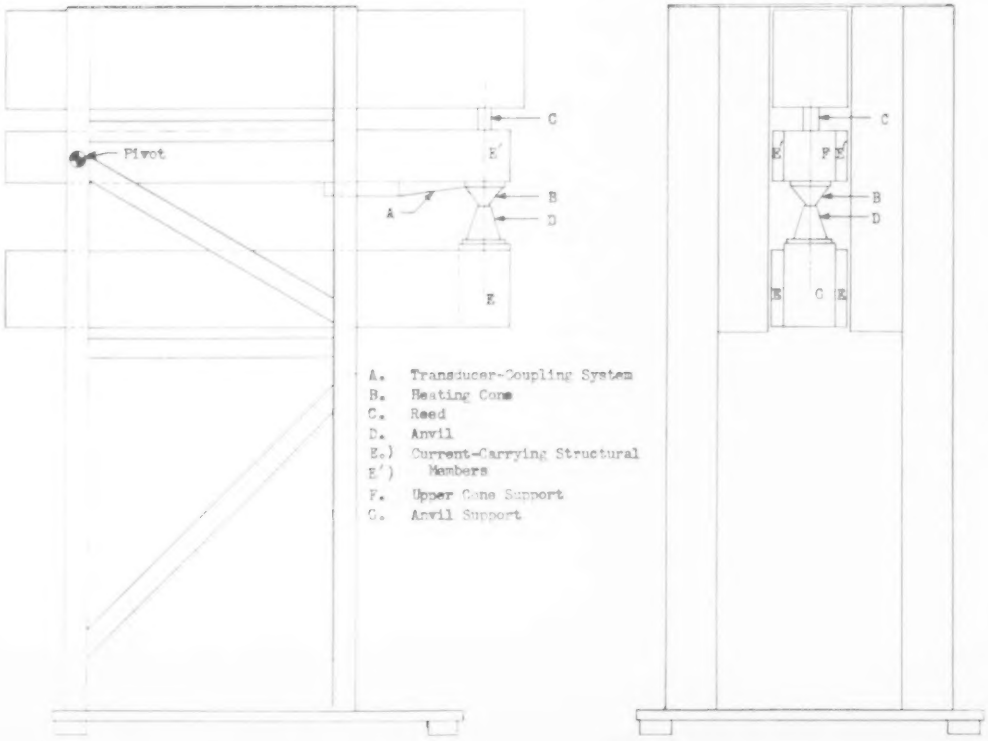


Fig. 4 Schematic diagram of ultrasonic welding array modified for warm welding

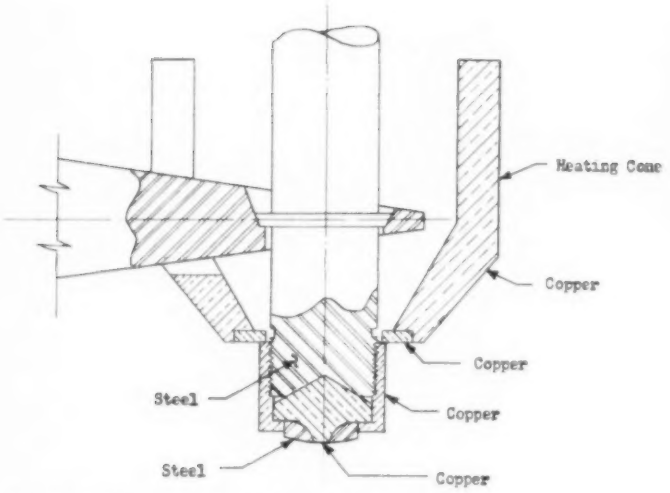


Fig. 5 Resistance-heated ultrasonic-welding tip array

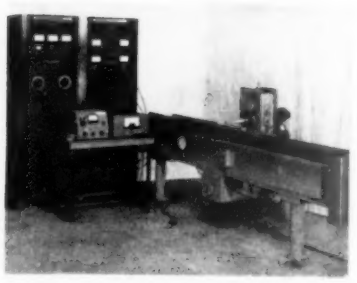


Fig. 6 Ultrasonic continuous-seam roller-type welder

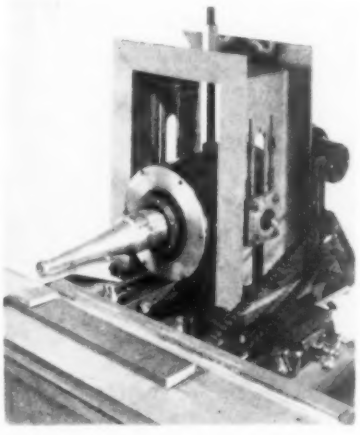


Fig. 7 Welding head of ultrasonic roller-type welder

Ultrasonic Roller-Type Welding Equipment

The ultrasonic seam-welding investigations for the project were conducted with the roller-type welding array shown in Figs. 6 and 7. The transducer-coupling assembly on this array was ball-bearing and slip-ring mounted, the slip rings providing power delivery to the transducer from the 2000-watt electronic generator shown in the background. The close-up of the welding head in Fig. 7 shows the welding tip, located at the forward end of the lateral transducer-coupling, as a 1-in. disk having a 3-in. face radius. The entire welding head was rotated by means of a series of motor-driven belts and pulleys which permitted reasonable control over angular velocity and translation of the traversing bed, which moved at a speed equivalent to the peripheral speed of the welding tip. The parts to be welded were clamped between the tip and the traversing bed, static load was applied through a compressed-air cylinder, and vibratory energy was introduced while the workpieces were translated between the two moving parts.

Evaluation of Capabilities of Spot-Type Welding Equipment

Much of the information and experience with ultrasonic welding prior to this investigation had been obtained with 1100-H14 aluminum. Consequently, this material was used as a means for appraising the capabilities of the laboratory spot-type welding array and modifications thereof. For such experimentation, conditions of power, force, tip radius and time were selected on the basis of the equipment limitations and the best available information at the time the experiment was made.

One study was oriented to determining the criticality of frequency tuning of the ultrasonic equipment. The possibility of measuring energy transmitted through the weld zone as an indication of weld quality was also investigated; such a technique promises a means for evaluating weld quality at the time the weld is made. Other experiments were related to evaluation of the original and the heavy-duty transducer-coupling systems.

Frequency Criticality

Frequency setting and control are basic to effective operation of an ultrasonic system, particularly a system from which optimum results are desired. Accordingly, since sheet thicknesses and material characteristics under study were different from those encountered in earlier work with ultrasonic welding,

Table 1 Representative Strengths of Ultrasonic Room-Temperature Spot Welds in 1100-H14 Aluminum

Sheet gage, in.	MIL-W-6860 requirements for resistance spot welds			Transducer system	Ultrasonic Welds				
					Welding conditions			Fracture load, lb	
	Minimum for single weld	Minimum Average ($n = 5$)	Minimum Average ($n = 20$)		Power level, watts	Clamping force, lb	No. specimens tested	Minimum	Mean
0.032	165	205	220	Original	375	150	3	250	260
					450	350	3	250	280
					525	350	3	260	270
0.040	225	275	300	Original	450	200	6	310	320
					500	300	15	310	325
0.050	295	340	392	Original	700	250	3	360	390
					1000	350	4	360	400
0.050	295	340	392	Heavy	1100	300	5	350	400
					1200	250–350	20	360	425
0.064	400	495	535	Heavy	1200	350	4	450	490
0.081	530	655	707	Heavy	1300	300	5	630	680

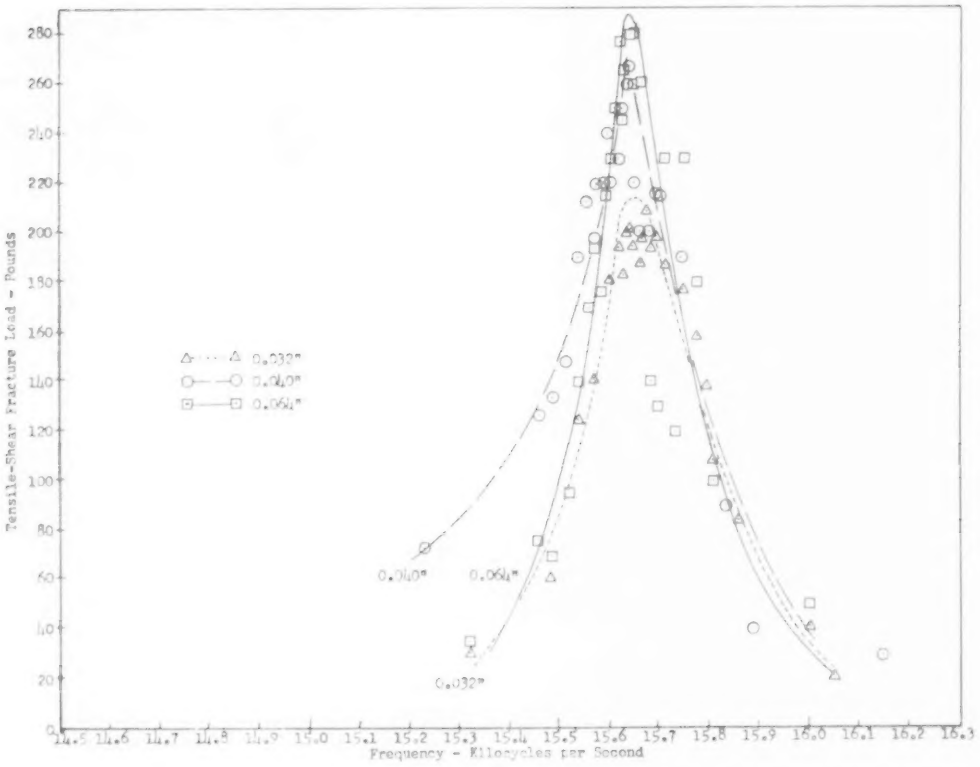


Fig. 8 Effect of frequency variation on strength of ultrasonic welds in 1100-H14 aluminum

experimentation was conducted to determine the effect of sheet thickness on frequency criticality.

Using thicknesses of 0.032-, 0.040- and 0.064-in. 1100-H14 aluminum, a series of tests was made to establish weld-strength values developed over a narrow range of frequencies that spanned the system design frequency. The ultrasonic power level was varied for the different gages: for the 0.032-in. material, the maximum power was 325 effective watts to the transducer; for 0.040 in., 550 watts; and for 0.064 in., 565 watts. Other machine settings were held constant at 165-lb clamping load, 1.5-sec ultrasonic exposure time, and 3-in. tip radius.

The data obtained are plotted as curves in Fig. 8. It is apparent that, under the experimental conditions used, frequency control becomes more critical as the material to be welded becomes thicker, and that under conditions of limited power, good control is essential for the heavier-gage materials of concern in this program.

Evaluation of Weld Quality by Transmitted Energy

Elastic vibratory energy delivered to the weldment can be estimated presently on the basis of true electrical watts delivered to the transducer, such measure-

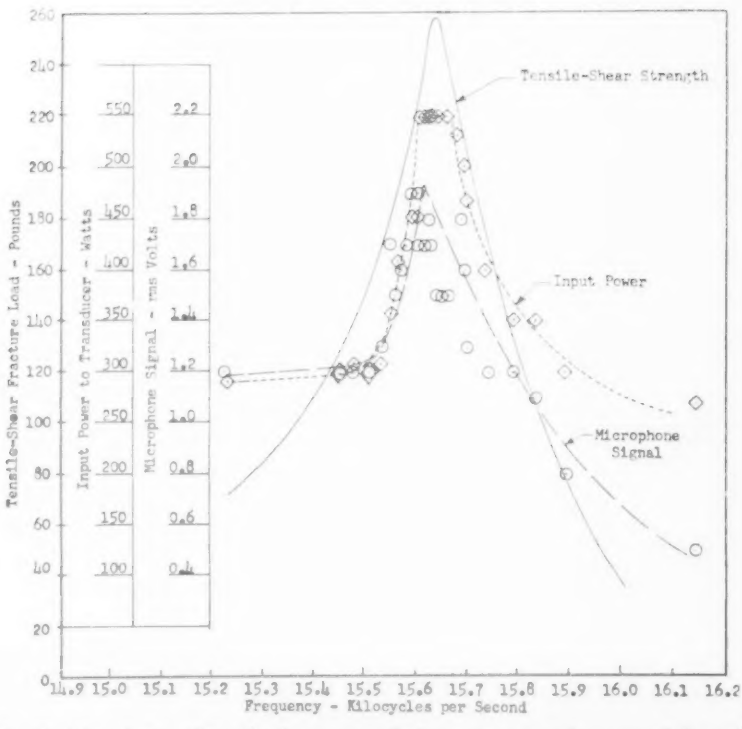


Fig. 9 Interrelation of tensile-shear strength, input power and energy delivered through the weld zone in ultrasonic welding of 0.040-in. 1100-H14 aluminum

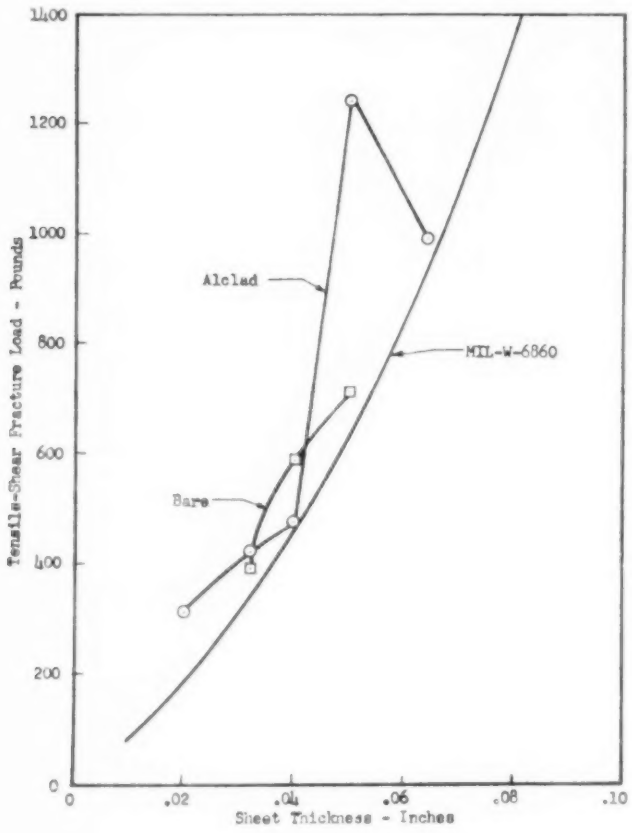
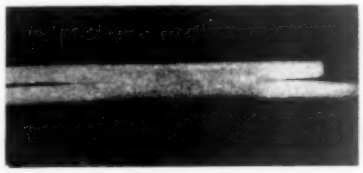
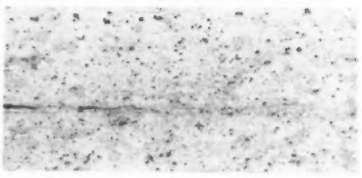


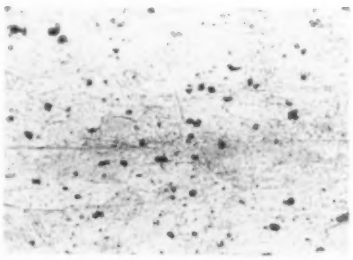
Fig. 10 Comparison of average ultrasonic weld strengths in 2024-T3 bare and Alclad aluminum alloys with Mil-W-6860 requirements for resistance spot-weld strength



a. X 15



b. X 150



c. X 500

Fig. 11 Photomicrographs of ultrasonic weld in 0.020-in. 2024-T3 bare aluminum alloy as welded. Keller's Etch. (Reduced by ½ upon reproduction)

ments being routinely determined with accuracy. Prior explorations had indicated the possibility of ascertaining weld quality by monitoring energy delivered through the weldment while a weld is being made. For further evaluation of this concept, a microphone element mounted on the side of the steel tip of the reflector anvil of the standard laboratory spot welder was used to monitor the relative energy level (not its absolute value) passing through the weld into the reflector anvil. Observations were made in conjunction with and subsequent to the frequency-tuning sensitivity studies described above, using the same material, sheet thicknesses and welding conditions.

Figure 9 shows plots of weld strength, input power and microphone reading (indication of energy delivered through the weld), as a function of frequency tuning of the system; the strength curve was reproduced from the plot of Fig. 8. The agreement among these three measurements indicates good possibility that a firm relation exists between weld strength and microphone voltage obtained from energy transmitted through the weld.

Evaluation of Original and Heavy-Duty Transducer-Coupling Systems

The sheet-joining capabilities of the two transducer-coupling systems were evaluated by tests on 1100-H14 aluminum in the thickness range of 0.032 to 0.081 in. A summary of representative data obtained generally with an ultrasonic pulse time of 1.5 sec and a tip radius of 3 in. is presented in Table 1. These observations were selected as representative of generally factorially-designed experiments, involving in excess of 1000 observations obtained with

Table 2 Representative Strengths of Ultrasonic Room-Temperature Spot Welds in Bare and Alclad 2024-T3 Aluminum Alloy

		MIL-W-6860 requirements for resistance spot welds			*Ultrasonic Welds*								
					Welding Conditions								
Material	*Sheet gage, in.*	*Minimum for single weld*	*Minimum average* ($n = 3$)	*Minimum average* ($n = 20$)	*Transducer system*	*Power level, watts*	*Clamping load, lb*	*Pulse time, sec*	*Tip radius, in.*	*No. specimens tested*	*Fracture load, lb Minimum*	*Fracture load, lb Mean*
Bare	0.032	260	320	347	Original	900	275	1.5	3	10	280	390
	0.040	345	425	460	Heavy	1400	350	1.5	1.5	4	520	590
	0.050	465	575	620	Heavy	1500	350	5	1.5	4	580	740
Alclad	0.020	140	172	187	Original	700	200	1.5	3	3	270	310
	0.032	260	320	347	Original	900	275	1.5	3	10	370	420
	0.040	345	425	460	Original	900	300	1.5	3	20	390	470
	0.050	465	575	620	Heavy	1250	300	3	1.5	4	1180	1240
	0.064	690	850	920	Heavy	1250	300	5	3	5	930	990

approximately 100 combination variables in welding conditions and material thicknesses.

For convenient comparison, the military specifications (MIL-W-6860) for standard resistance-spot-weld strength in 1100-H14 aluminum are provided in columns 2, 3 and 4 of the table. This MIL-W-6860 information takes into account the number of specimens to be tested to achieve a standard shear-strength value; e.g., the 0.032-in. material, when resistance spot welded, must demonstrate a minimum shear strength of 165 lb, an average for three specimens of 205 lb and an average for 20 specimens of 220 lb.

Review of the data presented in the table shows that increasing power requires increasing clamping force, and that the power required to weld 1100-H14 aluminum in the indicated thickness range, in order to meet or exceed military specifications, is in the approximate range of 375-1300 watts. The original system operating in the range of 700-1000 watts just succeeds in meeting military specifications for 0.050-in. material. The heavy-duty system exceeds the specifications by a comfortable margin at 1200 watts, and it is probable that a somewhat-higher clamping force will effect further increase in strength values for this system in the same power range. Under the conditions tested, the heavy-duty system appears to be marginal in meeting the specifications for the 0.064- and 0.081-in. thicknesses.

Work done subsequent to the assembly of data presented in Table 1 has established the power-handling capability of the heavier system, operating from a single 2000-watt ultrasonic generator, to be in the range of 1700-1800 watts and when operated by more powerful driving equipment, in the range up to about 2800 watts. Also subsequent to the assembly of data in the table, clamping forces in the 500-lb range have been briefly examined under conditions of satisfactory operation with the heavy-duty system.

Ultrasonic Room-Temperature Welding of Structural Aluminum Alloys

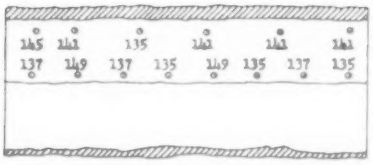
It was a primary intent of this program to develop ultrasonic welding for aircraft structural applications. Accordingly, aluminum alloys 2024-T3 and 7075-T6 were investigated with the view to welding both at room temperature and at elevated temperatures.

This section describes the results of vibratory welding of these materials at room temperature, including a study of required surface preparation. Early efforts made with the original transducer-coupling system were most successful with the thinner gages. The heavy-duty system required such extended effort and time to achieve practicable performance that its effectiveness in extending the thickness range for joining these alloys could not be adequately explored. This more powerful system, however, did permit significantly increased strengths in the thicker gages.

Most of this experimental work was carried out with single-lap tab specimens, each of which contained a single weld. Tensile-shear strengths were established by testing the specimens in self-aligning jaws of a standard hydraulic testing machine, load being applied at a constant rate of 600 lb per min until failure occurred. Representative weld specimens were sectioned and mounted for metallographic evaluation.

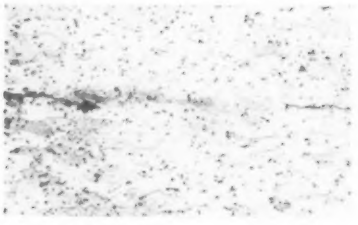
Surface Preparation

1. 2024 and 7075 Alclad Aluminum Alloys. Surface-cleaning studies in connection with earlier ultrasonic-welding investigations had reasonably well established the requirement for pre-weld cleaning of 1100 aluminum sheet, as well as of similar wrought or extruded aluminum, to consist simply of removal of heavy soil and surface lubricants. This is usually accomplished with a degreasing agent or commercial detergent solution. No available evidence indicates that deoxidizing cleaners are needed or that control of shelf life



a. Microhardness readings at noted locations on photomicrograph "b" below

b. X 27



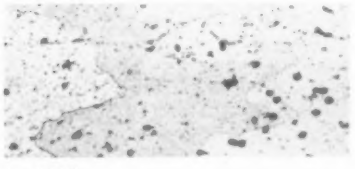
c. X 150

Fig. 12 Photomicrographs of ultrasonic weld in 0.032-in. 2024-T3 bare aluminum alloy as welded. Keller's Etch. (Reduced by 45% upon reproduction)

a. Microhardness readings at noted locations on photomicrograph "b" below

b. X 27

c. X 150



d. X 500

Fig. 13 Photomicrographs of ultrasonic weld in 0.032-in. 2024-T3 bare aluminum alloy solution-heat-treated and water-quenched after welding. Keller's Etch. (Reduced by 50% upon reproduction)

a. As welded

b. Solution-heat-treated and water-quenched after welding.

Fig. 14 Photomicrographs of ultrasonic welds in 0.032-in. 2024-T3 Alclad aluminum alloy showing integrity of Alclad layers. Keller's Etch. X150. (Reduced by 50% upon reproduction)

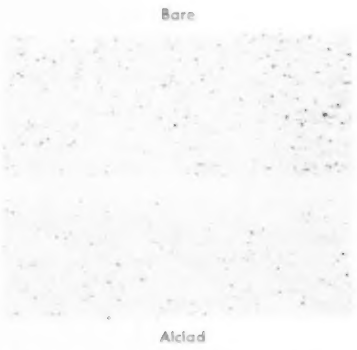


Fig. 15 Photomicrograph of typical ultrasonic weld between sheets of 0.032-in. 2024-T3 Alclad and 0.040-in. 2024-T3 bare aluminum alloys. Keller's Etch. X150. (Reduced by 50% upon reproduction)

after cleaning contributes to the quality of ultrasonic welds in 1100 aluminum.

Inasmuch as the aluminum cladding on such alloys as 2024 and 7075 is essentially 1100 aluminum, these Alclad materials were cleaned for ultrasonic welding only with detergent solutions as described above. The welds produced after such cleaning appeared to meet effectively the static strength requirements of resistance spot welds according to MIL-W-6860, and also to withstand exposure to thermal cycling.

2. 2024 Bare Aluminum Alloy. Preliminary efforts to join the bare structural aluminum alloys indicated that the same situation did not prevail as with surfaces clad with 1100 aluminum, and it was concluded that the bare materials required a more involved cleaning or deoxidizing procedure.

The procedure selected was a caustic etch, designated the C-2 process, which had proved effective on other types of surfaces. This consisted of degreasing, followed by a 2-minute immersion in 10% sodium hydroxide solution at 180 to 190° F, a 2-minute immersion in 50% nitric acid solution at room temperature and a 4-minute immersion in 20% phosphoric acid solution at room temperature.

Evaluation of the relative effectiveness of degreasing and of C-2 cleaning of the bare material was made with test specimens of 0.032-in. 2024-T3 bare aluminum alloy using the then-satisfactory welding conditions. The results tabulated below reflect the necessity for deoxidization treatment:

Pre-weld treatment	*Fracture load, lb*			*MIL-W-6860 strength requirements, lb*	
	Minimum	*Maximum*	*Mean*	*Minimum*	*Mean*
Degreased and deoxidized	300	400	372	260	347
Degreased only	180	400	290	260	347

Inasmuch as the cleaning problem associated with meeting military specifications is a costly phase of Class "A" resistance spot welding, and particularly since such welds must be produced within a few hours after cleaning, study was made with the bare aluminum alloy to ascertain the significance of shelf life after cleaning. Tests were carried out primarily with 0.032-in. 2024-T3 bare material, using machine settings which provided 900 watts true power, 275-lb clamping load, 1.5-sec pulse time and a 3-in. tip radius. The results are tabulated below:

Sheet thickness, in.	*Elapsed time after deoxidization*	*No. specimens tested*	*Fracture load, lb*			*MIL-W-6860 strength requirements, lb*	
			Minimum	*Maximum*	*Mean*	*Minimum*	*Mean*
0.032	1 hour	10	290	420	356	260	347
0.032	12 hours	10	280	440	365	260	347
0.032	24 hours	10	330	410	370	260	347
0.032	48 hours	10	280	440	390	260	347
0.036–0.038	6 months	4	400	650	520	325	425

On the basis of these data, reoxidization of the sheet material after cleaning does not appear to be detrimental to the quality of ultrasonic welds in the materials tested, although this conclusion can be only tentative until confirmed under atmospheric conditions prevalent in a number of manufacturing areas.

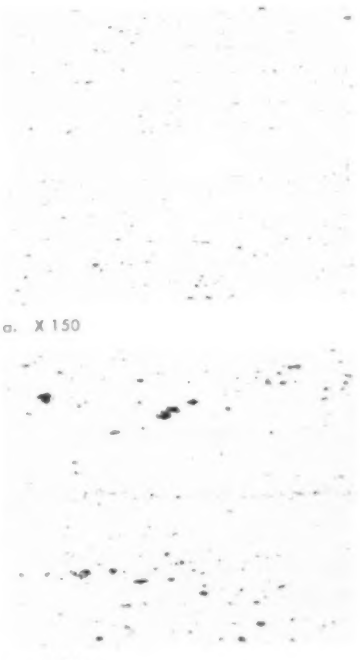
In summary, therefore, it may be said that Alclad or other bright-finish aluminum surfaces seem to require no cleaning other than degreasing prior to ultrasonic welding; that cleaning of the bare structural aluminum alloys containing appreciable surface discoloration seems to require but one deoxidizing operation; and that the time elapsing between cleaning and welding does not appear to be a factor in connection with the ability of ultrasonic welds in these materials to meet aircraft strength specifications.

Ultrasonic Weld Strength

During the course of the program, effort was expended to extend ultrasonic welding to heavier gages of the aircraft structural alloys of interest. Previously-described equipment developments and detailed investigations of welding-machine settings eventually resulted in the ultrasonic-welding capabilities evidenced in the data of Table 2 and graphically shown in Fig. 10. These data, assembled at the conclusion of the program, were obtained at the optimum welding conditions tested. Figure 10 also shows the minimum requirements of MIL-W-6860 for resistance spot welds in these aluminum alloys.

Review of the data indicates that ultrasonic welding is by no means limited to foil thicknesses or to the very light gages of these alloys. In particular, the larger transducer-coupling system permitted substantial extension of the sheet-thickness range. It is especially noteworthy that the strengths of joints in 0.020- and 0.050-in. Alclad material exceed the requirements of MIL-W-6860 by substantial percentages.

Further exploration with the heavy-duty system and with other improved welding arrays should extend the ultrasonically-weldable thickness range still further.



a. X 150

b. X 500

Fig. 16 Photomicrographs of ultrasonic weld in 0.032-in. 7075-T6 Alclad aluminum alloy showing integrity of Alclad layers. Keller's Etch. (Reduced by 50% upon reproduction)

Metallographic Evaluation

1. Welds in 2024-T3 Bare Aluminum Alloy. The effects of ultrasonic spot welding on the microstructure of 2024-T3 bare aluminum alloy were considered. Figures 11 and 12 show typical as-welded microstructures obtained in the weld zone between sheets of 0.020- and 0.032-in. material respectively. Severe working of the metal has occurred at the interface (partially dependent upon the effects of the various machine settings used), and but little structural change has occurred in other areas of the weldment. External deformation accompanying the welds was small, usually less than about 5% of the total cross-sectional thickness.

Microhardness surveys were made on some of the sectioned weldments. The facsimile sketch of Fig. 12*a* shows little variation in hardness readings (diamond pyramid scale) taken across the weld zone, indicating that neither extreme work-hardening nor over-aging of the work area has occurred.

For further evaluation of the metallurgical continuity of the weldment, specimens of the above were subjected to solution heat treatment at 920° F (±10°) for 10-20 min, followed by a water quench and natural aging. Typical photomicrographs of these specimens are shown in Fig. 13. Continuity of the grain structure over the former interfacial area is indicative of the metallurgical bond attainable by the ultrasonic-welding process. Microhardness surveys made on the 0.032-in. specimen after heat treatment (Fig. 13*a*) show good uniformity of properties across the weld zone, consistent with the normally expected base-metal hardness.

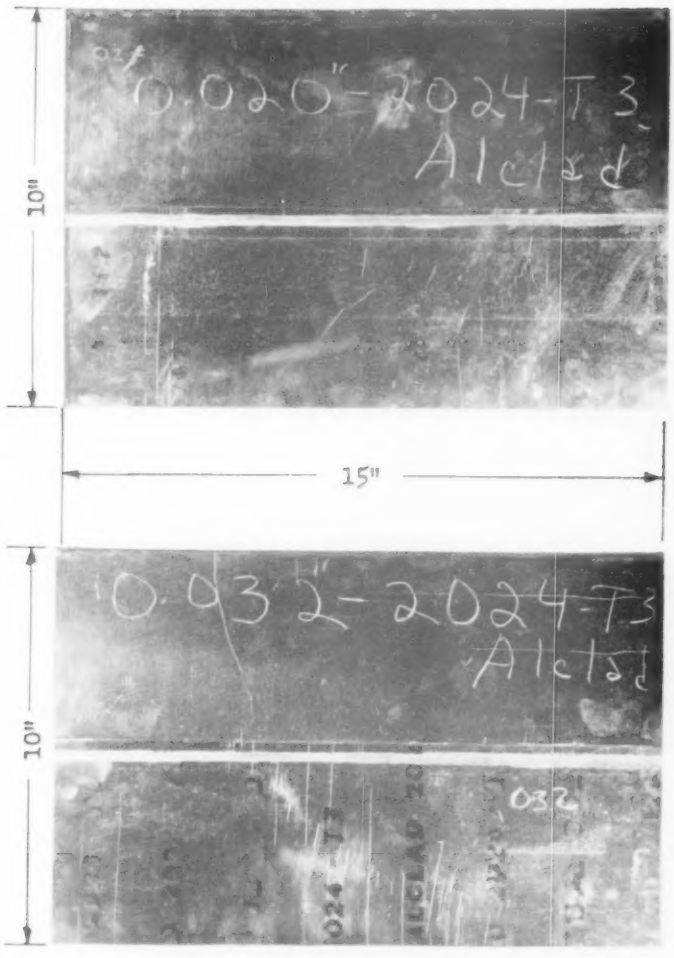


Fig. 17 Seam welds produced by ultrasonic roller-type welder

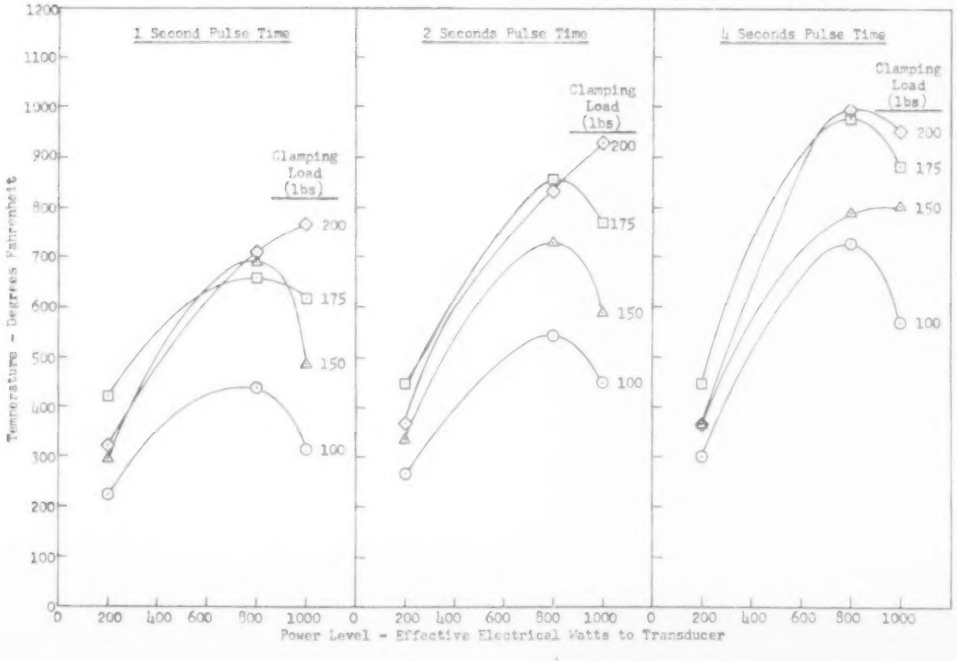


Fig. 18 Effect of power level on temperature achieved in weld zone with parameters of clamping load and pulse time

2. Welds in 2024-T3 Alclad Aluminum Alloy. Figure 14 shows photomicrographs of a weld between two sheets of the 0.032-in. thickness of this clad material, both before and after solution heat treatment for 10 min at 920° F, followed by a cold-water quench. It is significant that, in the welding of the clad alloy, welding forces have caused severe internal deformation of the interface but have not destroyed the cladding in the weld zone. This is especially significant when it is considered that strengths achieved with the Alclad material easily meet military specifications for strength of resistance welds. Strengths of these joints would therefore appear to depend upon reinforcement of the weld-area metal by the stronger, less-ductile base metal. Heat treatment of these weldments showed no significant effect upon microstructure.

3. Welds Between 2024-T3 Bare and 2024-T3 Alclad Sheet. The microstructure produced by ultrasonic welding of 0.032-in. 2024-T3 Alclad to 0.040-in. 2024-T3 bare aluminum alloy is shown in Fig. 15. A sound metallurgical bond was obtained, again without destroying the integrity of the Alclad layer, the structure obtained being similar in appearance to the ultrasonically-welded 2024-T3 Alclad aluminum alloy of Fig. 14.

4. Welds in 7075-T6 Alclad Aluminum Alloy. Available in sheet only as Alclad, the 7075-T6 aluminum alloy was ultrasonically spot welded with exploratory results comparable to those obtained with 2024-T3 Alclad material. Figure 16 illustrates a weld between two sheets of 0.032-in. material; as with the 2024-T3 Alclad alloy, the cladding layer was not disrupted by the welding process, the bond being essentially between the thin aluminum cladding skins. Because no rupture has occurred in the cladding, corrosion resistance of such welds should be excellent.

Welding of Sheet to Extruded Sections

As a convenient substitute for extruded specimens, aluminum alloy plate was used in connection with the welding of the structural aluminum alloys. Tabs of 0.032-in. 2024-T3 bare aluminum alloy were ultrasonically spot welded to $\frac{3}{4}$-in. 2024-T3 bare plate material and also to $\frac{1}{4}$-in. 7075-T6 Alclad plate; in addition, tabs of 0.032-in. 2024-T3 Alclad sheet were welded to $\frac{1}{4}$-in. 2024-T3 bare plate material.

These welded specimens were not tested in tensile-shear in the usual manner. When the sheet material was manually peeled from the heavier member, failure did not occur in the bond zone; instead, the weld zone sheared out of the thinner sheet, leaving a nugget attached to the plate material. These observations seemingly confirmed tentative conclusions reached in earlier work, i.e., that the ultrasonic-welding process is limited only by the weldability of the thinnest member of the weldment and that the second member may be of unlimited thickness.

Feasibility of Ultrasonic Seam and Area Welding

Using the improved model of the roller-type ultrasonic welder illustrated in Figs. 6 and 7, ultrasonic seam welds were successfully used to join sheets of 0.020-, 0.025- and 0.032-in. 2024-T3 Alclad aluminum alloy in panels from 10 to 20 in. long. These welds were achieved at power levels and clamping loads comparable to those used in the ultrasonic spot welding of these materials and at nominal welding speeds of from 3 to 6 ipm.

Weld strengths in a number of such specimens were determined by shearing the welded panels into $\frac{1}{2}$-in. wide tensile strips and testing in the same manner as for the spot-welded specimens. Welds in 0.020-in. 2024-T3 Alclad material, produced at 400-watts power, 200-lb clamping load, and a welding rate of 3.5 ipm, showed average strengths of 168 lb per $\frac{1}{2}$-in. specimen for a single weld seam. Specimens containing two weld seams spaced $\frac{1}{2}$ in. apart showed average strengths of 363 lb per $\frac{1}{2}$-in. specimen. Typical seam-welded panels are shown in Fig. 17, the panels still containing the sheet identification inking which was not removed during degreasing.

Later work involving substantially-increased power delivery was carried out on 20-in. long panels of 2024-T3 Alclad material. Using a power level of 1500 watts, clamping load of 350 lb and welding rate of 6.5 ipm, ultrasonic seam welds were produced which showed average strengths, for $\frac{1}{2}$-in. wide specimens, of 604 lb in the 0.025-in. material and 707 lb in the 0.032-in. material.

This work thus indicates the feasibility of ultrasonic seam and area welding of the structural aluminum alloys, and the equipment and process appear to be suitable for studies, including the development of strength data, oriented to the ultrasonic joining of specific structural aluminum-alloy configurations.

Ultrasonic Elevated-Temperature Welding

Exploratory work has indicated that the ultrasonic weldability of a material is associated with the mechanical properties of the weld metal, such as tensile or shear strength, hardness, elastic modulus, and elongation. It has also been established that ultrasonic room-temperature weld-

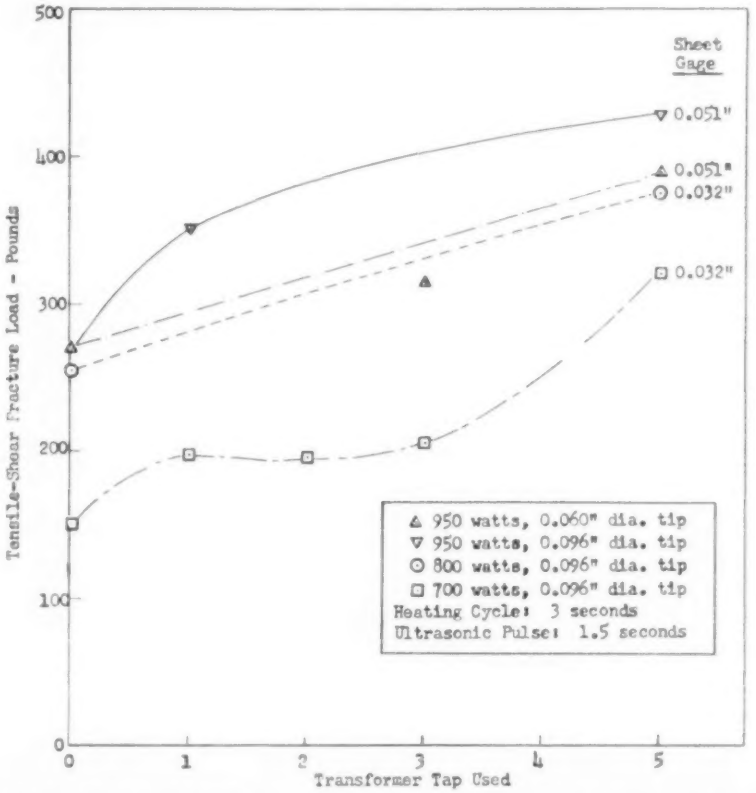


Fig. 19 Effect of applied resistance heat on ultrasonic weld strength in two gages of 2024-T3 Alclad aluminum alloy

ing induces a very transient, exceedingly localized heating in the weld zone which transiently and favorably alters the mechanical properties in the weld metal.

Present limitations in the weldability of materials and material thicknesses appear to arise either from insufficient power to produce the necessary vibration-induced internal displacement or deformation, or from insufficient internal temperature rise to effectuate favorable alteration of the mechanical properties so that bonding can take place at presently-available power levels, or from the interaction of both these factors.

Experience has shown that materials not currently weldable at room temperature with available power levels can be ultrasonically welded if the weld-zone temperature is raised, and that this can be conveniently accomplished with electrical-resistance heat. Studies were therefore made in connection with introducing auxiliary heat into the weld zone, and the quality of vibratory welds thus produced was compared with the quality of ultrasonic room-temperature welds.

Specifically, these "warm welding" studies involved consideration of the following factors:

1. The temperature rise in the weld zone associated with room-temperature vibratory welding.

2. Utilization of auxiliary heating in conjunction with vibratory welding in order to (a) produce welds in heavier materials than can be welded without heat; (b) produce better welds in material gages presently weldable without heat; or (c) produce the same quality welds in presently-weldable gages at lower ultrasonic power levels or with shorter pulse times.

3. The effect of elevated temperatures on the properties of the weld material.

Temperature Rise in Weld Zone During Room-Temperature Welding

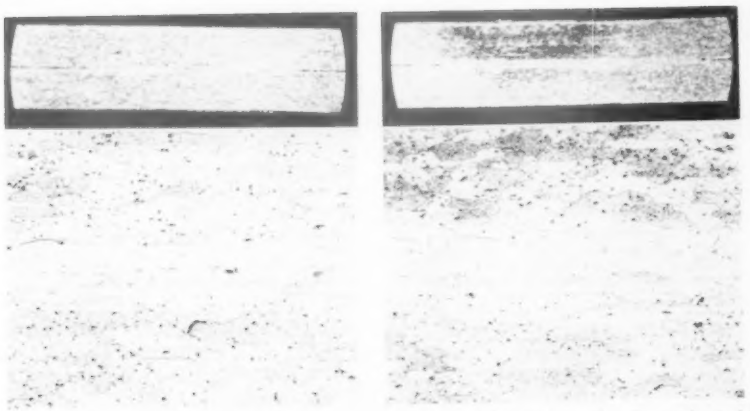
It has long been known that ultrasonic room-temperature welding produces a localized temperature rise at the interface between the sheets being welded. Assuming a planar heat sink, a theoretical analysis[1] made of the magnitude of this temperature rise indicated that, on the basis of an actual energy input to the weld zone of an assumed 200 watts, a rise of about 600° F might be expected after about 1 sec.

Efforts were made to investigate this temperature rise experimentally. Initially, a technique involving thermocouples between the sheets in the weld zone was attempted. This method appeared not to indicate the temperature developed because of the difficulty of locating thermocouples of reasonable size precisely in the exceedingly-small central zone. Furthermore, the thermocouples became welded into the weldment, introducing incompletely-understood side effects.

A more effective method of measuring the temperature rise involved the thermal emf generated in welding strips of dissimilar metals. A strip of 1100-H14 aluminum, approximately ½ by 1½ in., was prepared with wire of the same material welded to one end; a similar assembly was made of Monel sheet and Monel wire. Each lead wire was metallically joined to a copper wire, the copper joints being separately immersed in ice baths. The copper wires were connected to an amplifier which operated a Brush oscillograph with a response of 100 cycles per sec. The two dissimilar strips were placed in position for welding, with a contact area of approximately 0.012 sq in., and the metals were ultrasonically welded, using a 3-in. spherical radius welding tip, clamping loads ranging from 100 to 200 lb, power levels of 200, 800 and 1000 true electrical watts, and pulse times up to 5 sec. The thermal emf output of the bimetal junction was recorded continuously on the oscillograph during the welding period. Three tests were made for each combination of clamping force and power level, the average emf value being determined in each case.

To insure accurate conversion of the recorded emf to temperature, a separate thermocouple produced by welding aluminum and Monel was calibrated using molten lead. This method was checked by similarly exposing a chromel-alumel thermocouple and comparing the results with a standard temperature-millivolt curve for chromel-alumel. Good agreement was obtained between results for the aluminum-Monel and the chromel-alumel thermocouples.

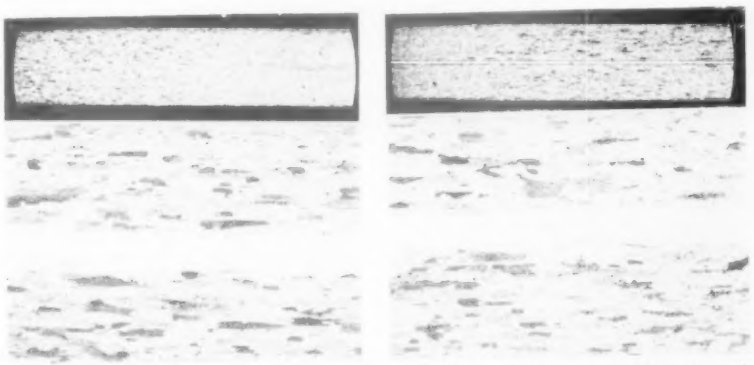
The data obtained are summarized in the curves of Fig. 18 which shows the temperature achieved as a function of power level, with parameters of clamping load and pulse time. Certain trends in these data are apparent. It



a. Welded without resistance heating

b. Welded with the ultrasonic resistance-heated array at Tap 5

Fig. 20 Photomicrographs of ultrasonic welds in 0.032-in. 2024-T3 Alclad aluminum alloy welded both with and without heat. Keller's Etch. Above, X17; below X230. (Reduced by 50% upon reproduction)



a. Welded without resistance heating

b. Welded with the ultrasonic resistance-heated array at Tap 5

Fig. 21 Photomicrographs of ultrasonic welds in 0.050-in. 2024-T3 Alclad aluminum alloy welded both with and without heat. Keller's Etch. Above, X18; below, X180. (Reduced by 50% upon reproduction)

appears that, within limits, increased clamping force improves energy delivery and increases the temperature achieved. For example, at 200 watts, temperature increased with increased clamping load up to something over 175 lb but dropped at 200 lb, suggesting that the 200-watt power level is inadequate to drive the transducer-coupling system as effectively at 200 lb as at the lower clamping forces. At power levels of 800 and 1000 watts, the utilization of power becomes increasingly effective as the clamping load is increased up to and including 200 lb; it appears that, with the tip radius and materials studied, at least 200 lb is required to handle the 1000-watt power level.

Ultrasonic Welding of Preheated Specimens

Prior to operating with the resistance-heated ultrasonic-welding array, preliminary experiments on the effect of auxiliary heating were made by preheating aluminum-alloy specimens in an oven. The welding tips of the ultrasonic system were also preheated with a torch to equivalent temperatures so that the specimens would not be quenched when removed from the oven and clamped between sonotrode tip and reflector anvil. Welding-tip temperature was monitored by clamping a thermocouple between these members so that tip temperature could be closely matched to oven temperature.

Tab specimens of 0.050-in. 2024-T3 Alclad aluminum alloy were preheated to temperatures of 250, 500 and 700° F, and were welded using a 3-in. tip radius, 350-lb clamping load, 1050-watts power, and 1.5-sec pulse time. Tensile-shear strength data on these specimens are summarized below:

Preheat temperature	*No. of tests*	*Fracture load, lb*		
		Maximum	*Minimum*	*Average*
None	5	570	530	544
250° F	6	710	590	632
500° F	7	890	690	819
700° F	7	940	750	845

It is apparent that even with low-temperature preheat, below the temperature at which aging could be expected in this alloy with short transient thermal cycles, appreciable improvement in strength was produced. Data obtained with the 700° F preheat indicate that full advantage may be taken of the ultrasonic-thermal combination somewhat below this temperature.

Ultrasonic Welding with Resistance Heating

Ultrasonic elevated-temperature welding experiments were carried out on 0.032- and 0.050-in. 2024-T3 Alclad aluminum alloy. The resistance-heating array provided five transformer tap settings that could be used to obtain progressive increases in electrical-resistance current within the range of approximately 800–1500 amp, thus providing progressive increase in heating capacity. Tests were made over this range of tap settings, using copper-cored welding tips of two different sizes. The resistance heat was introduced for a 3-sec preheat period, followed instantaneously by a 1.5-sec ultrasonic pulse; power delivery to the transducer was in the range of 700-950 true watts, the maximum power that this transducer-coupling array would accept, and clamping loads were in the range of 200-300 lb. Weld specimens produced in this manner were tested in tensile-shear and were examined metallographically.

The results of the strength tests are plotted in Fig. 19, which shows the increase in strength obtained with applied resistance heat. In the 0.032-in. material, the effect of increasing the power input from 700 to 800 watts (with a clamping load of 200 lb) is readily apparent. Weld-area measurements made on the specimens produced at 800-watts power without heat and with the No. 5 tap setting indicated the weld-area increase with heat to be approximately 22%, while the strength increase was about twice as much. Thus the effect of externally-applied heat appeared to be that of increasing both bond area and weld quality. Weld strength likewise increased with applied heat for the 0.050-in. Alclad material, as shown in the two upper curves of Fig. 19.

Photomicrographs of typical weld specimens are shown in Figs. 20 and 21, which illustrate weldments produced with the same welding array but without applied heat, as well as those preheated with transformer tap No. 5.

In the 0.032-in. material (Fig. 20), it is apparent that no rupture of the cladding layer has occurred, either at the interface or on the outer layer of either specimen. In both cases, thickness deformation at the weld zone was in the order of 3%. Typical solid-state bonding occurred in both instances, and the preheated specimen shows only a small heat-affected zone. The increased weld area obtained with applied heat is evident. The higher-magnification photomicrographs show the nature of the interfacial bond under both conditions.

The photomicrographs of the welds in the 0.050-in. material (Fig. 21), like those in the thinner sheets, show the typical solid-state bond zone, no rupture of the cladding and negligible thickness deformation. There was apparently no effect of the heating on the microstructure in the weld zone with this thicker material.

Conclusions

1. The power-handling capacity of the ultrasonic-welding transducer-coupling system was significantly expanded, with no evident limitations on substantially-greater increases.

2. The effective range of ultrasonic spot-type welding, as determined by static-shear strength, has been extended to include 0.064-in. 2024-T3 Alclad aluminum alloy, 0.050-in. 2024-T3 bare aluminum alloy and 0.081-in. 1100-H14 aluminum.

3. Metallographic studies indicate good-quality solid-state bonding with all materials investigated.

4. Surface cleaning in preparation for ultrasonic welding is less critical than for Class A resistance spot welding; Alclad aluminum surfaces require only degreasing, bare aluminum alloys require but one deoxidizing operation, and the time elapsing between cleaning and welding is apparently not significant.

5. Ultrasonic spot-type welding can be effectively supplemented with heat at temperatures below critical levels for the aircraft structural aluminum alloys.

6. The feasibility of ultrasonic seam-type welding was demonstrated with 2024-T3 Alclad aluminum alloy in gages up to 0.032 in.; the achievement of area-type welds appears to be only a matter of development.

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A THEORY FOR PREHEATING OF PLAIN, LOW-CARBON STEELS

Improved weldment performance which, under many conditions, results from preheating is attributed by the author primarily to reduced microcracking

BY E. PAUL DEGARMO

SYNOPSIS. While it has been well established that, under many conditions, preheating improves the performance of plain, low-carbon steel weldments, there has been no satisfactory explanation as to why it produces these results. Six possible effects of preheating—reduced microhardness, increased width of the heat-affected zone, reduced shrinkage stresses, changed hydrogen content, more favorable microstructure and reduced microcracking—are considered, and it is shown that existing research results rule out all but the last as possible primary causes of the improvement resulting from preheating. From a consideration of the requirements for microcracking—retained austenite and hydrogen—a theory is developed which states that it is the elimination of retained austenite at low temperatures, due to the greatly reduced cooling rate below 400° F which results from preheating, that accounts for the beneficial results obtained. Based upon this theory, certain conditions are indicated for which preheating will and will not produce improved performance.

Introduction

During the past fifteen years a number of investigators, including Kennedy, Flanigan, Krefeld, Nippes and this writer, have shown that proper preheating of low-carbon steel weldments, made of plate not over 3/4 in. thick, produces marked improvement in performance. Considerable practical experience has borne out this fact. For example, the welding engineer of a very large construction company stated that they had never had a failure where preheating was used, and he considered his company's "know-how" regarding preheating to be a valuable trade secret. Yet few phases of welding have produced more arguments than has preheating. It appears unquestionable that preheating has not been used as widely as it deserves. This is unfortunate since failure to take advantage of any procedure that will enable better weldments to be produced more economically is a loss to the welding industry.

A number of reasons could be cited for the apparent lack of acceptance of preheating. However, one is of special and interesting importance. This is the fact that no completely satisfactory theory has been available to explain how preheating accomplishes the results that are obtained by its use, or to enable one to predict under what conditions preheating will or will not work. In the absence of such understanding, hesitancy in using the procedure is not surprising.

The purpose of this paper is not to extoll or denounce preheating. Instead it is an attempt to develop a theory to explain why preheating works. It would be most desirable if complete experimental proof of the theory could also be presented. Unfortunately, this cannot be done. It appears unquestionable that research of the type needed will have a considerable statistical element, thus requiring rather extensive tests. However, the theory will be based entirely upon previously-published research results of various investigators. It is hoped that the presentation of the theory will prove helpful in defining the limits for the beneficial use of preheating, and at the same time will serve to spur research investigation to prove or disprove the theory.

Possible Effects of Preheating

From a consideration of the preheating process, it appears that the improvement which it produces might be due to any, or all, or a combination of some of six factors. These are: (1) reduced microhardness in the heat-affected zone, (2) increased width of the heat-affected zone with an accompanying decrease in the sharpness of transition between the various microstructures, (3) reduced shrinkage stresses, (4) changed hydrogen content, (5) more favorable (stronger, more ductile, etc.) microstructure and (6) reduced microcracking. Most of these results have been reported by various investigators. All might logically be expected to result from the nature of the preheating process. All of them might be expected to produce improved performance. It is possible, and even probable, that nearly all actually do add something toward improved performance. However, the basic problem is to determine the key factor, or factors, without which the improved performance resulting from preheating would not occur.

The paragraphs which follow will examine each of the six factors and attempt to show that available research results do evaluate these factors and provide the support for a theory for preheating. All of the remarks pertain only to plain, low-carbon steel not over 3/4 in. thick.

Research Evidence

(1) *Reduced microhardness in the heat-affected zone.* It has been well established by DeGarmo[1] and others that very high microhardness may exist in the heat-affected zone of nonpreheated welds and that this hardness is much less in preheated welds. Thus, such reduction in hardness might contribute substantially to the improved ductility of preheated welds.

That this reduction in microhardness, *in itself*, does not account for the improved performance is clearly shown by the work of Daniels, Gardner and Rood.[2] These investigators made welds with both E6010 and E6016 electrodes in such a manner that all welds had the same cooling rate at 1000° F regardless of preheat temperature. Chemical analyses and microstructures were found to be virtually identical. When they were made at 72° F, the E6016 welds had considerably lower transition temperatures than those made with E6010 electrode. Preheating at 400°

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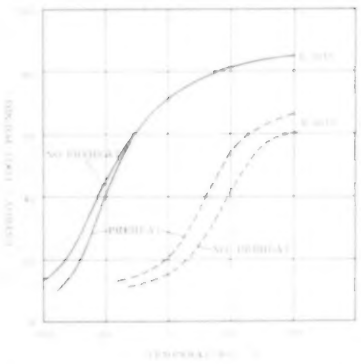

Fig. 1 Temperature-energy curves for E6010 and E6016 welds having same cooling rate at 1000° F, made with and without preheat (Daniels, Gardner and Rood)

F produced almost no change in the transition temperature of the E6016 welds, but did reduce the transition temperature of the E6010 welds considerably. This is shown in Fig. 1. Thus while there was no change in hardness in this case from the no preheat to preheated conditions, the results were distinctly different.

Flanigan and Mieleu,[3] in an extensive investigation, also found very little correlation between bend test performance and microhardness. Therefore, reduced microhardness alone cannot be the critical factor.

(2) *Increased width of the heat-affected zone.* That preheated welds have wider heat-affected zones and less sharpness of transition between the various microstructures than are found in nonpreheated welds has been shown by DeGarmo[4] and his associates and by others. The possibility that the sharp changes in microstructures might constitute metallurgical discontinuities or notches has been suggested.

The work of Daniels, Gardner and Rood[2] also demonstrates that the improved performance of preheated welds cannot be due to this factor. Their preheated and nonpreheated E6010 welds had the same cooling rates at 1000° F and the same microstructures, yet the transition temperatures were different.

Flanigan and Mieleu[3] also investigated, directly, the effect of the width of the heat-affected zone and found very little correlation between bend-test performance and this factor.

(3) *Reduced shrinkage stresses.* The possibility that preheating might reduce the residual stresses and thereby improve weldment performance was proposed quite a few years ago. Unfortunately there is one major difficulty with this proposition. This writer[4] has demonstrated that preheating at 400° F does not reduce the high, longitudinal residual stresses to any great degree. Experiments, producing results illustrated in Fig. 2, showed that preheated welds, containing residual stresses of considerable magnitude, were equal in performance in bending to stress-relieved welds which had virtually no stresses. Thus this third possibility for explaining the effectiveness of preheating is eliminated.

(4) *Changed hydrogen content.* The advent of low-hydrogen electrodes, and the very successful results obtained through their use, served to emphasize the role of hydrogen in weld performance. This led to the possibility that preheating reduced the hydrogen content in weldments made with ordinary cellulosic coatings, and thus hydrogen might be the critical factor in the improved performance brought about by preheating.

This theory was quite decisively disproved by the research of Flanigan,[3] in which he demonstrated that increasing the preheating temperature up to 375° F actually increased the total amount of contained hydrogen and, at the same time, produced larger bend angles in the specimens tested. Flanigan quite reasonably postulated that since preheating promotes slower cooling, which enables more hydrogen to escape, it must also permit more hydrogen to be absorbed. It must be conceded, however, that there is the possibility that preheating may permit the escape of hydrogen from certain harmful regions, although the total hydrogen content increases. This does not seem very probable.

(5) *More favorable microstructure.* With respect to microstructure the evidence is not so direct. It has been shown by DeGarmo[4] and others that the microstructure of preheated welds normally is substantially different from that obtained without preheating. Figure 3 shows typical microstructures resulting from the two procedures. It has repeatedly been demonstrated that preheated welds, having such different microstructures, provide performance superior to nonpreheated welds. However, in the work by Daniels, Gardner and Rood[2] it was found that nonpreheated and preheated E6010 welds performed differently, even though they

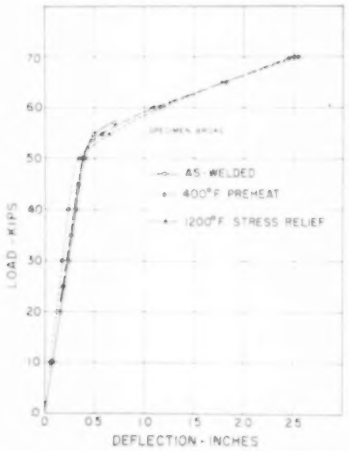

Fig. 2 Relative bend-test performance of as-welded, preheated and stress-relief heat-treated specimens (DeGarmo)

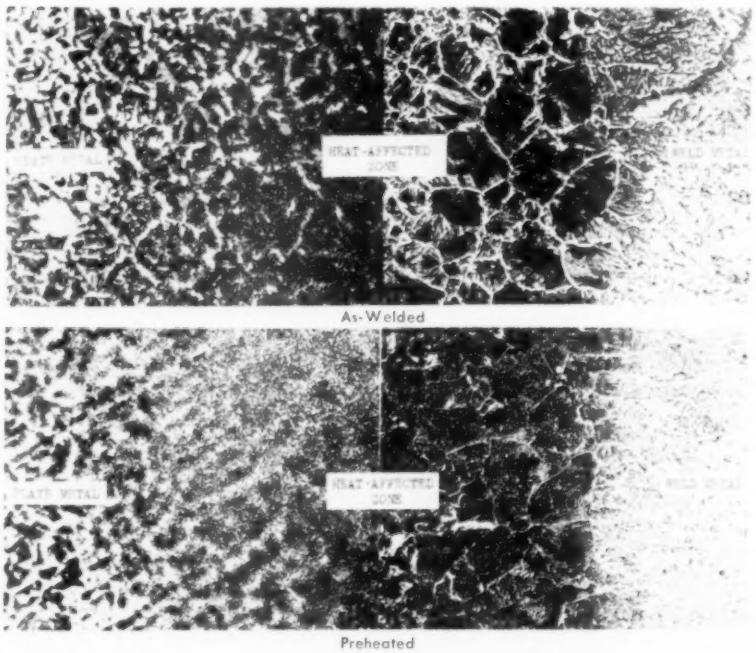

Fig. 3 Microstructures of preheated and nonpreheated welds

had the same microstructure, obtained when the cooling rates at 1000° F were the same.

It should be kept in mind that the cooling rates of these welds were not the same at temperatures substantially below 1000°F. However, it does not appear that differences in microstructure, at least in the usual sense, can account for the improved performance of preheated welds.

(6) *Reduced microcracking.* It has been very well established that microcracking adversely affects the performance of welds. With the other five factors eliminated as the direct causes for the improvement resulting from preheating, the possible relationship between preheating and microcracking merits close scrutiny.

Several investigators have studied the relationship between microcracking and weld performance, and between preheating and microcracking. Flanigan, Bocarsky and McGuire[6] found that slower cooling rates below 400° F produced marked improvements in the bend angles of E6010 welds, but little effect on E6016 welds. This confirmed earlier work of Hess and his associates[7] which showed that, if welds were held for several hundred seconds at 400° F, a definite improvement in ductility and strength occurred.

In looking for the reason for the improved performance obtained by slower cooling rates below 400° F, Flanigan and Mielen[5] made an extensive investigation of microcracking. They found good correlation between bend-test performance and microcracking. They concluded that the primary benefit from preheating was due to the slowing of the low-temperature cooling rate and subsequent inhibition of microcracking.

Voldrich[8] investigated the relationship between plate temperature and underbead cracking, and found that when the plate temperature of crack-sensitive steels exceeded a certain minimum, microcracking dropped to a negligible amount. Typical results are shown in Fig. 4.

There thus is considerable evidence that preheating reduces the cooling rate below 400° F and reduces microcracking, and that this in turn brings about improved performance. At least, microcracking appears to be the only one of the six factors, listed previously, which can be related directly to the improved performance which results from preheating.

How does preheating reduce microcracking? If one concludes that preheating reduces microcracking and thus improves weldment performance, there still remains the question of how it reduces microcracking. It is necessary to have an explanation for this phenomenon in order to utilize preheating effectively. A review of the cause of microcracking is helpful in this.

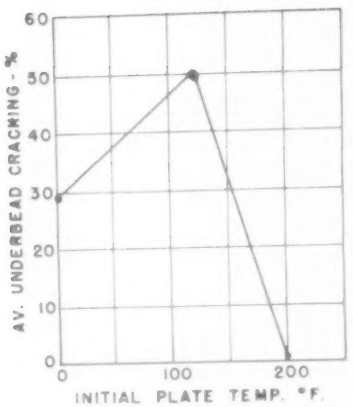

Fig. 4 Relationship between preheat temperature and microcracking (Voldrich)

It has been quite well established that, for underbead cracking to occur, both retained austenite *and* hydrogen must be present as a weldment cools. The steel dissolves considerable amounts of atomic hydrogen at high temperatures. This must be rejected as transformation of the austenite occurs at lower temperatures, due to the greatly decreased solubility of hydrogen in the transformed constituents as compared with the solubility in austenite. In order to escape, the atomic hydrogen must diffuse to some surface where it can reform molecular hydrogen and become a gas. If the hydrogen, in attempting to escape to the surface, comes to a discontinuity, diffusion is interrupted and the gas collects and forms a very high pressure. Retained austenite, transforming at low temperatures, forms islands of martensite which not only act as discontinuities to prevent the diffusion of the hydrogen but also are brittle and under an additional state of stress due to the volume change which accompanies the austenite transformation. Microcracking is thereby started in these hard and brittle microconstituents. It is thus established that, for microcracking to occur, both retained austenite and hydrogen must be present.

Several persons have reported evidence that microcracking may not actually occur in some cases until strain occurs. Thus, examination of unstrained specimens might not show any microcracking but, if these same specimens were subjected to load, microcracking and subsequent poor performance would result. As yet, this theory does not appear to be definitely established.

If both retained austenite and hydrogen must be present in order for microcracking to occur, it follows that the absence or elimination of either should prevent microcracking. The situation

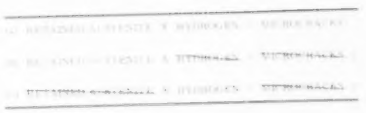

Fig. 5 Schematic representation of the relationship between retained austenite, hydrogen and microcracking

with respect to these two, mutually requisite factors is illustrated in Fig. 5.

The advent of low-hydrogen electrodes gave a method of eliminating hydrogen and thus eliminating microcracking and improving performance. These electrodes were so successful that virtually all attention was focused on hydrogen and very little thought given to the other requisite for microcracking — retained austenite.

If the theory concerning the formation of microcracks is correct, the elimination of retained austenite should be just as effective in eliminating microcracking as is the elimination of hydrogen. This leads to a theory that the improvement due to preheating is because of the reduced cooling rate below 400° F, which results from its use, and the consequent elimination of retained austenite, which in turn prevents the formation of microcracks.

If this theory is correct, it follows that preheating will be effective when, and only when, it produces adequate reduction in the low-temperature cooling rate. As a corollary, it might be stated that when welding conditions are such that without preheating the cooling rate is slow enough so that austenite is not retained, the use of preheating will not produce improved performance.

Unfortunately, there is no direct and conclusive proof of this theory as yet. However, the theory appears to be consonant with all of the known facts. Further, since old and some rather new information supports the corollary.

Application of the Theory

If the theory is correct, it is possible to specify certain conditions under which preheating will and will not improve performance. Preheating will be effective in situations where without it there is a rapid cooling rate which can be considerably reduced by its use. Rapid cooling results where the section thickness is not great, so that high heat input is not required, and the amount of material available for heat absorption and heat conduction is relatively great. Thus, single-pass welds on plate up to $\frac{3}{4}$ in. in thickness, with a considerable amount of surrounding metal, will provide such conditions. Many other configurations can be visualized which would result in rapid cooling.

It likewise is not difficult to specify

conditions wherein preheating cannot be expected to be effective. One of these would be in the welding of thicker sections of low-carbon steel. If such sections are welded by multi-pass welding, without permitting the interpass temperature to drop abnormally, the heat of subsequent passes modifies the retained and transformed austenite of previous passes and provides preheating for any passes which follow. Thus, the addition of preheating will have little or no beneficial effect. This phenomenon has been observed. It has even been found that on 1" c-m. steel low-hydrogen electrodes showed virtually no superiority over ordinary electrodes, probably attributable to this phenomenon.

Another condition would be where very high heat inputs are used so that considerable heat flows ahead of the arc and thus provides sufficient preheating to prevent the retention of austenite. Several persons have proposed the possibility of such a phenomenon and several have reported obtaining unusually good performance from weldments made under such conditions. Unfortunately there appear to have been almost no published results of this nature.

It should be mentioned that an attempt by the author to obtain direct proof of the theory was only partially successful. The work must be described as incomplete. Considerable time and money will be required to complete the necessary experiments.

Conclusion

Here then is a theory for preheating which is improved but appears to be entirely compatible with known facts. Some recent research gives indirect support to its validity. It is hoped that this statement of the theory will serve three purposes: (1) call forth additional existing evidence to support or disprove the theory, (2) stimulate additional research to prove this theory or to provide some other theory, and (3) provide a basis for more intelligent use of preheating. If it accomplishes any one of these purposes the effort will have been repaid.

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RESEARCH NEWS

Alloying Metals

With publication of the fourth volume in its new Monograph Series, Alloys of Iron Research provides a valuable source of reference for engineers, metallurgists and others concerned with the effects of certain alloying metals on carbon steel and on both simple and complex alloy steels and cast iron. The present 533-page work, consisting of a correlated summary of all the important literature on the use of boron, calcium, columbium and zirconium as alloying metals, will be indispensable to the designer of metals to be used at very high temperatures and under high pressures. These alloying elements have made important contributions to such modern developments as atomic reactors, guided missiles and jet engines.

Alloys of Iron Research is one of Engineering Foundation's oldest and most important projects. It was established in 1930 for the purpose of making a survey of worthwhile research work on carbon and alloy steels and on cast iron, as reported in technical literature all over the world, and of making its findings readily available to engineers and others needing it.

The new reference—entitled *Boron, Calcium, Columbium, and Zirconium in Iron and Steel*—is the fifteenth monograph brought out by Alloys of Iron Research and the fourth in a special series that has been in preparation since 1946 to cover the phenomenal advances in metallurgy made during the war. In addition to providing a reliable foundation for further research, the special series rounds up essential information previously scattered through hundreds of books and journals in many languages. Still in preparation are volumes dealing with manganese in iron and steel and carbon in iron and steel.

Authors of the fourth monograph bring to the work a rich background of experience in the metallurgical field. They are R. A. Grange, of the U. S. Steel Corp.; F. J. Shortsleeve, D. C. Hilty, W. O. Binder and C. M. Offenhauer, with the Electro Metallurgical Co.; and G. T. Motock, of the Olin Mathieson Chemical Corp. The volume has been carefully reviewed by authorities in the field and approved for publication by the Iron Alloys Committee.

John Wiley and Sons has published the Fourth Monograph for Engineering Foundation. Copies are available from the publisher at 440 Fourth Avenue, New York 16, N. Y. The price is $14.00.

ENERGY ABSORPTION STUDIES OF WELDS IN TEMPERED MARTENSITIC BASE METAL

Study made to provide a comparison of the behavior of T-1 steel with killed and rimmed steel and thus evaluate its useful properties in overcoming the hazards of low-temperature fracture

BY W. H. BRUCKNER AND C. A. ROBERTSON

INTRODUCTION. The use of the tension-impact testing method has previously[1, 2] been found to provide most useful data in determining energy absorption, ductility, transition temperature and the micro mechanism of fracture. The advent of the introduction and now widespread use of the tempered martensitic steels, such as the T-1 grade steel has brought with it a new concept of weldability and such high energy absorption potential as to favor the use of the T-1 steel for engineering structures. Where economic considerations make it impossible to fabricate an entire structure of the T-1 grade steel, the material may still perform usefully as a section of higher energy absorption welded into the main structure for the purpose of arresting the propagation of brittle cracks.

The present study was made in order to provide a comparison of the behavior of the T-1 grade steel with steels of killed and rimming grade and thus to evaluate its useful properties in overcoming the hazards of low-temperature fracture. It was especially desired to investigate the micromechanism of failure in order to learn why the tempered martensitic structure should be so sharply different in fracture behavior from the as-rolled structures of the conventional structural steels.

Materials and Methods

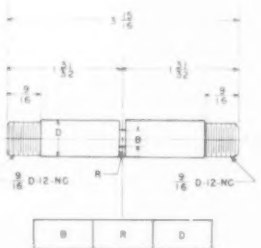
The test data obtained in this study involved the combination of three basic materials: rimmed steel, T-1 steel and weld metal deposited from E12015 electrodes. This type of composite weld would be involved in providing a welded crack-stopper section of high energy-absorption potential in a structure of less costly material made of rimmed steel. The rimmed steel and the T-1 steel were in the form of $\frac{3}{4}$-in. thick plates. The chemistry and mechanical properties of the materials as given in the tables for the E12015 deposited metal refer to all-weld metal and not to the actual weld between the rimmed and T-1 steels.

The welds were made normal to the rolling direction of both steel plates according to the design and procedure shown in Fig. 1. The two series of notched tension-impact tests made on the welds involved the weld deposited region and the heat-affected zone on the T-1 side of the above weld. These regions were selected for testing by placing the specimen notch in the respective areas. The tension-impact tests of the unaffected base metal of the T-1 steel were made from the as-received, quenched and tempered steel plate.

Fig. 1 Welding procedure for butt weld of T-1 to rimmed steel with E12015 welding electrode

Procedures and welding conditions: Root opening $\frac{1}{8}$ in., root edge $\frac{1}{16}$ in. Torch bevel set at 35 deg to vertical electrodes for passes—1, $\frac{1}{8}$ in. rod; 2, $\frac{5}{32}$-in. rod, grind out underside; 3, $\frac{5}{32}$-in. rod; 4-9, $\frac{5}{32}$-in. rod. Current—$\frac{1}{8}$-in. rod, 125 amp dc; $\frac{5}{32}$-in. rod, 175 amp dc; $\frac{3}{16}$-in. rod, 210 amp dc

The design of the axial tension-impact specimen is shown in Fig. 2 as developed in the previous work cited. The length of this specimen was always placed in the rolling direction of the steel plate. The notch diameter was



B	R	D
0290	0089	0525

Fig. 2 Design and dimensions of B-type notched tension-impact specimens

measured before and after fracture, thus permitting the evaluation of ductility as reduction of area.

The tension-impact properties of the rimmed steel either in the heat-affected or unaffected zone were not determined in this study, since previous studies of this material in the as-rolled condition are a matter of record. Our main concern was the transition from the rimmed steel into the T-1 which would be required to stop a crack which had propagated in the rimmed steel plate. The data given in the paper for tension-impact tests of rimmed and killed steels were taken from previous publications as cited earlier in the paper.

The testing method which was followed to determine the micromechanism of fracture of the unaffected T-1 base metal was the partial fracture method which has also been described in previous publication. It consisted of providing a multiplicity of notched tension-impact specimens which had been loaded in impact with less initial energy in the pendulum than required to cause complete fracture. Under these conditions the pendulum rebounds and is caught to prevent reloading of the specimen. Sectioning and metallographic examination of the notch volume of the impact specimen then reveals the microstructure resulting from impact loads below and up to complete fracture. The results of this part of the study are given later in the microstructures and discussion thereof.

Data Obtained

The results of tests made with notched tensile-impact specimens in which the notch was placed, respectively, in the unaffected base metal of T-1 steel, the heat-affected zone of the T-1 side of the composite weld and, lastly, in the weld resulting from the mixture of rimmed and T-1 steels are given in Tables 3, 4 and 5. These data are summarized in Fig. 3 for energy absorption and in Fig. 4 for percent reduction of area.

A further comparison is made in

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Paper to be presented at the AWS National Spring Meeting to be held in St. Louis, Mo., Apr. 14 to 18.

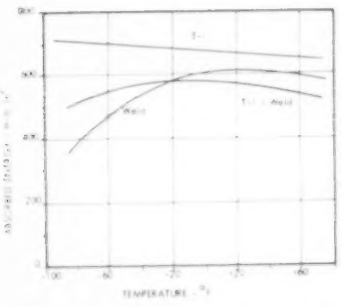

Fig. 3 Tension-impact test; absorbed energy vs. temperature for T-1 steel, T-1 weld interface and weld region

Figs. 5 and 6 for the unaffected base metal of rimmed, killed and T-1 steel under comparable conditions with Type B notch-impact specimens as shown in Fig. 2.

The data on the micromechanism of failure are shown as a series of microstructures illustrating the progressive effects of increasing initial energy given to the tension-impact specimen during test. All of the photomicrographs are so oriented that the vertical direction is parallel to the maximum principal stress during the impact stress. Figures 7, 8 and 9 are at × 100 and show the progressive opening of voids associated with the stringer inclusions. Figure 10 at lower magnification shows the root of the notch on either side of the figure and the large void which has opened in the region of the notch. The final fracture of the T-1 steel in tension impact is shown in Figs. 11 and 12 which give the transverse fractures between the metal fibers produced by the voids. The transverse fractures were found to be oriented at about 45 deg to the specimen axis. In this respect, and in relation to their fracture surface appearance, the transverse fractures are representative of shear failure.

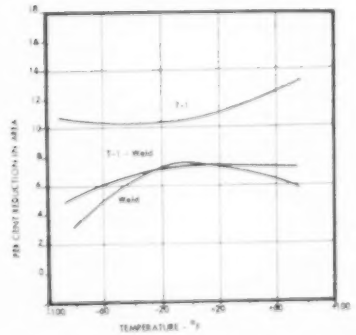

Fig. 4 Tension-impact test; percent reduction in area vs. temperature for T-1 steel, T-1 weld interface and weld region

Table 1—Chemical Composition, % of Steels

	Material		
Element	Rimmed	T-1	Electrode
C	0.18	0.19	0.04
Mn	0.42	0.85	1.10
P	0.013	0.013	0.017
S	0.031	0.015	0.025
Si	0.02	0.28	0.43
Cu	0.23	0.19	
Cr	0.07	0.54	
Ni	0.14	0.93	1.60
Al	0.003	0.31	
Mo			0.83
V			0.25

Table 2—Physical Properties of Steels

Material (Heat No.)	Yield strength, psi	Ultimate strength, psi	Elongation, % in 2 in.	Reduction in area, %
Rimmed (16445)	34,700	68,200	36.5	52.6
T-1	111,900*	126,600	23.0	69.1
E12015	113,000†	120,000†	22.0	57.0†

* Based on 0.2% offset.
† As-welded.

Table 3—Tension-Impact Data for Specimens of T-1 Steel

Specimen No.	Testing temperature, °F	Energy absorbed, ft-lb/in.²	Reduction in area, %
TA5-4	41	695.0	9.4
TA5-5	72	671.0	13.1
TA5-6	−96	723.7	11.6
TA5-7	−94.5	691.5	8.1
TA5-8	−93	723.7	10.8
TA5-9	76	637.0	13.2
TA5-10	76	627.0	12.9
TA5-11	77	659.0	13.3
TA5-22	−10	660.0	11.2
TA5-21	−10	660.0	9.7

Discussion of the Data

The data shown in the curves of Fig. 3 indicate that, for the tension-impact tests made with Type B specimens, the energy absorption is a maximum for the as-received, quenched and tempered T-1 steel. The energy absorption of the weld interface region of the T-1 steel is slightly lower than that of the starting material. The weld deposit, which is a result of admixture of rimmed and T-1 steel, has the lowest energy absorption, excluding the rimmed steel itself. At temperatures below 80° F, the energy absorption of the weld and T-1 weld interface tend to decrease to a slight extent, while the curve for the initial T-1 base metal tends to remain the same or even rise to a slight extent down to −90° F.

Table 4—Tension-Impact Data for the T-1 Weld Interface Specimens

Specimen No.	Testing temperature, °F	Energy absorbed, ft-lb/in.²	Reduction in area, %
R-7	−10	628.3	7.7
R-11	−90	476.9	4.1
R-21	−13	529.9	6.3
R-24	76	529.9	7.2
R-31	78	484.5	7.1
R-33	78	552.6	7.6
R-36	−74	552.6	5.9
R-38	−76	512.4	5.5
R-39	−9	563.3	7.1

Table 5—Tension-Impact Data for Specimens of Weld Region

Specimen No.	Testing temperature, °F	Energy absorbed, ft-lb/in.²	Reduction in area, %	Comments
R-13	78	507.2	3.5	Specimen failed in rimmed steel-weld interface
R-17	−83	325.5	4.1	
R-22	72	469.3	6.6	
R-34	74	605.6	5.5	See R-13
R-25	−8	586.9	8.2	
R-26	78	631.5	5.8	See R-13
R-32	−74	512.8	3.8	
R-35	−80	358.2	2.4	See R-13
R-37	−14	628.5	7.2	
R-23	−10	569.8	7.2	

The curves of Fig. 4, which give the percent reduction of area values, show a greater spread between the weld, weld interface and the base metal than does the energy absorption. Since the lowest testing temperature of −90° F used is above the transition temperature of all of the regions tested, there is not manifested the usual sharp loss of ductility common to the conventional as-rolled structural steels.

The full significance of the energy absorption and ductility relationship for the T-1 steel can only be seen from the curves of Figs. 5 and 6. Figure 5 shows that even in the most ductile condition of the rimmed and killed steel, the T-1 has 50% greater energy absorbing capacity, while below their transition temperatures the T-1 steel can absorb 700% more energy than the rimmed or killed steels. The ductility relationship shown in Fig. 6 is less favorable for the T-1 steel above the transition of the rimmed and killed steel, but there is no sharp reduction in ductility for the T-1 because at −90° F the T-1 is still above its transition temperature. Below the transition temperature of the rimmed and killed

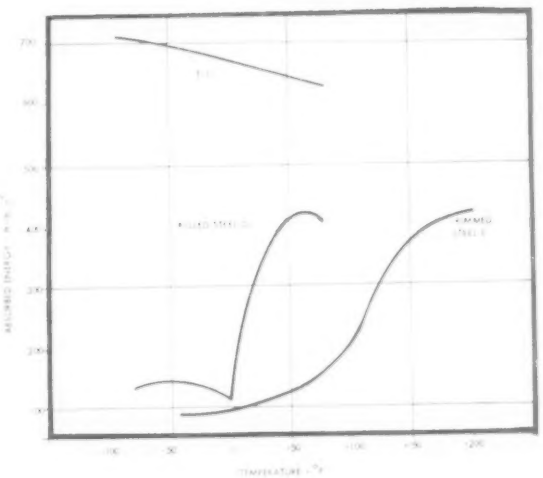

Fig. 5 Tension-impact test; absorbed energy vs. temperature for T-1 steel, rimmed steel E and killed steel D

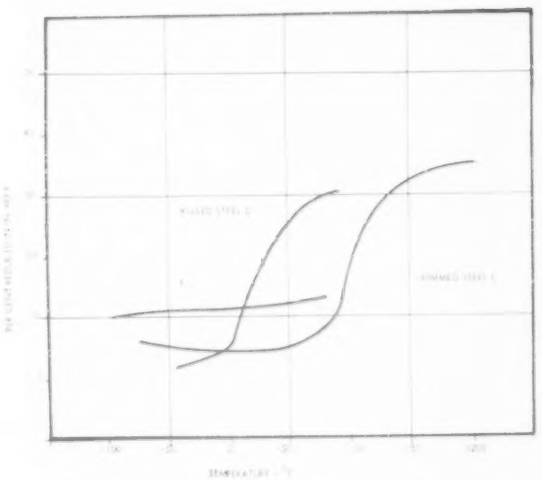

Fig. 6 Tension-impact test; percent reduction in area vs. temperature for T-1 steel, rimmed steel E and killed steel D

steels their ductility practically vanishes, but at these temperatures there is only a slight decrease in ductility of the T-1 from its initial value due to its shear type fracture down to at least −90° F.

It is seen, therefore, that a crack which would propagate in the rimmed steel and progress toward a welded crack-stopper of T-1 steel would make a gradual transition into zones of increasingly higher energy-absorbing capacity and be finally stopped in the T-1 base metal. If killed steel were substituted for the rimmed steel, it would be expected that the same gradual transition would exist across the composite weld with the T-1 steel, except that the composite weld metal would have higher energy absorption than when the admixture involved rimmed steel.

The evidence regarding the mode of fracture of the T-1 base metal in the tension-impact specimen is given partially in the selected series of microstructures of Figs. 7 to 12. The method of producing partial fracture specimens and sectioning them to determine the sequence of microstructural change leading to complete fracture has successfully shown that the uniformly distributed, short stringer inclusions, characteristic of T-1 steel, play an important part in its high energy absorbing behavior. It is seen from the microstructures that the lateral restraint produced in the specimen by the presence of the notch has caused a longitudinal separation of the base metal at one or more inclusions. This must mean that the lateral stress collapses in the region of complete separation leaving a metal fiber subjected mainly to a uniaxial stress. Final failure occurs by transverse fracture of the individual fibers after their ductility has been exhausted in uniaxial strain. It would therefore be expected that the T-1 steel would have a lower order of notch sensitivity than the conventional structural steels, since on the above basis the attainment of a high order of multiaxiality of stress is not possible with the T-1.

Because the stringer inclusions are present, it would be expected that a considerable difference should exist in properties of the T-1 parallel and transverse to the rolling direction. This

Fig. 7 Voids opening up around inclusions in the direction of longitudinal stress. Specimen AT5-19, initial energy 460.5 ft-lb per sq in., unetched. X 100. (Reduced by 1/4 upon reproduction)

Fig. 8 Greater density of voids in center of specimen. Specimen AT5-25, initial energy 544.8, unetched. X 100. (Reduced by 1/4 upon reproduction)

Fig. 9 Voids are greater in length than in preceding micrograph. Specimen AT5-18, initial energy 606.3, unetched. X 100. (Reduced by 1/4 upon reproduction)

Fig. 10 Large void at center of notched specimen, specimen AT5-28, initial energy 530.0, unetched. X14. (Reduced by $\frac{1}{4}$ upon reproduction)

Fig. 11 Lateral failure extending from lower end of large void in Fig. 10 to neighboring void. Specimen AT5-28, initial energy 530.0, unetched. X 200

difference has not been investigated with the tension-impact test nor have the effects of cross rolling been surveyed. The use of cross-rolling procedures to reduce the anisotropy are known to increase transverse properties, and the effects on the mechanism of fracture would be an interesting and possibly a productive research area.

Conclusions

The use of structural-steel base metal with a tempered martensite structure resulting from a quench-and-temper heat treatment favors a larger energy-absorption potential than is available from conventional structural steels of rimmed or killed grades. Furthermore, the data indicate that the heat-affected zone of a T-1 steel, which was selected as a representative of the tempered-martensite base metal, is not seriously lower in energy absorption or ductility than the initial base metal of T-1 steel. The weld deposit resulting from the admixture of rimmed steel and T-1 base metal with the weld from E12015 electrode has lower energy absorption and ductility than the T-1 base metal or weld interface, yet its properties are appreciably higher than those of the rimmed-steel base metal at low temperatures.

The use of a welded crack stopper of T-1 steel in a rimmed steel would appear to have ideal consequences in arresting the propagation of a brittle crack, since the energy-absorbing capacity increases across the weld into the weld interface and into the T-1 base metal.

The type and distribution of the nonmetallic inclusions which were found in the T-1 steel appeared to have a favorable effect in decreasing notch sensitivity in tension-impact test. The maximum principal stress of the tension-impact tests was in the rolling direction as were the stringer-type inclusions, thus causing voids to form at the inclusions as the transverse stress increased. The presence of the inclusion stringers is believed to enhance the ability of T-1 steel to fracture mainly in shear down to a temperature of $-90°$ F with a consequent large energy absorption.

The above data were obtained from studies of the micromechanism of fracture using the partial-fracture technique. It would be of considerable value to determine by the partial-fracture method the effects upon fracture of T-1 steel processed by means of different cross-rolling procedures and also by vacuum melting to afford control of inclusion content and distribution.

Fig. 12 Void in center indicating that lateral failure has occurred in three regions. Specimen AT5-28, initial energy 530.0, unetched. X 100. (Reduced by $\frac{1}{4}$ upon reproduction)

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COMBUSTION OF LIQUID HYDROCARBON FUELS FOR OXYGEN CUTTING

Application of known principles of combustion brought to bear on an experimental study of the characteristics of a liquid-fuel cutting torch

BY DIEU KHUONG-HUU, SHELDON S. WHITE AND CLYDE M. ADAMS, JR.

ABSTRACT. In order to increase the allowable performance limits of an oxy-fuel cutting torch, it is necessary to have a sound understanding of the mechanics of combustion, flame stabilization, flame blow-out, quenching, flash-back and flame propagation. A literature review of the subject is presented, and application of known principles of combustion is brought to bear on an experimental study of the characteristics of a liquid-fuel cutting torch using white, unleaded gasoline as the preheat fuel.

It was found that for a given gasoline flow rate, cutting speed increased with a decrease of the preheat oxygen flow rate, to the extent that a fuel-rich flame gave a much higher cutting rate than a stoichiometrically balanced flame.

In consideration of various fuels for cutting, the question of adiabatic flame temperature has been studied. It has been found possible to summarize the extensive determinations by Sachsse and Batholomé of computed flame temperatures in a single quantitative relationship, showing the pronounced effect of dissociation of combustion products on flame temperature.

Introduction

With more and varied types of liquid and gaseous hydrocarbon fuels becoming available for heating purposes, it is of interest to investigate their unique flame characteristics, and potential applicability to the fields of welding and cutting. And, to optimize the performance of any oxy-fuel torch, it is necessary to have a sound understanding of the mechanics of combustion, flame stabilization, flame blowout, quenching, flash-back and flame propagation. In particular, liquid fuels offer certain unique benefits as to portability, economy, storage and safety, but present problems in metering, mixing and flame maintenance and control. It is the purpose of this report to review some of the recent literature on flames and combustion, pertinent to oxygen cutting in general, and to present some data on the use of gasoline as a fuel for this process.

In order to obtain a fuel-oxygen mixture which will result in complete combustion, certain fundamental conditions must be fulfilled. These involve introducing the liquid fuel in such a way that rapid and thorough mixing with oxygen can take place, with the maintenance of the proper fuel-oxygen ratio under conditions of continuous flow. A highly turbulent scrubbing action accelerates the conversion of liquid fuel to vapor because partial atomization of the liquid provides a large amount of surface for evaporation. Atomization, evaporation and mixing should be accomplished prior to burning. However, the small volume of the cutting torch tip and the short residence time prevent the separation of these individual steps. Therefore, burning occurs in the presence of liquid fuel droplets. Browning and Krall[1] have shown that small droplets evaporate with sufficient rapidity to approximate a fine mist having essentially the same combustion properties as the completely vaporized fuel. Also, the experiments done by Graves and Gerstein[2] on a combustible mist indicate that the flame velocity and flammability limits are similar to those of premixed gaseous systems.

Flame stabilization is an essential part of the mechanism of combustion involved in high-speed flames. Williams, Hottel and Scurlock[3] have proposed the following model for this problem: consider a stabilized flame to be one which is held stationary at the torch tip. Then the flame to be studied is analogous to that of a Bunsen burner, the only difference being in the magnitude of the flame velocity. Although the maximum velocity of gases passing through a Bunsen tube is only some ten feet per second and that of the gases through the cutting torch several hundred feet per second, the underlying principles of the combustion processes are the same. The Bunsen burner provides a region above the orifice in which the velocity of the gas does not exceed the flame velocity. Therefore, the flame is held stationary. Near the port the transformation velocity is lower than the exit velocity of the combustible mixture, driving the combustion wave back. If the wave is somewhat removed from the solid rim, the burning velocity exceeds the gas velocity. Therefore, the wave moves toward the rim until an equilibrium position is reached at which the two velocities are equal. Flame or transformation velocity is defined as the speed relative to the unburned gases with which the flame front moves from the burned to the unburned gases. Lewis and von Elbe[4] gave a very clear description of the mechanism by which a flame is stabilized with respect to the burner rim.

Williams, *et al.*,[3] have shown a mechanism of flame stabilization, different from that of Bunsen flames, which could yield a source of greater heat release due to higher gas velocities. This method consists of the recirculation of the hot burned gases into the colder unburned combustible stream. This stabilization can be accomplished by placing a blunt object, such as a rod, in the gas stream, as shown in Fig. 1. Behind the obstruction, the velocity of the hot gas is very low because of flow separation. Thus, the combustion wave readily finds a position of equilibrium. The combustion products recirculate in the eddy region and preheat fresh combustibles, while a continuous pilot flame is anchored in the separated region. When this region is too small the flame is extinguished. The type of flame stabilization described above prevails, to some extent, in any welding or cutting tip due to eddying and recirculation at the abrupt exit, and the effect can be enhanced through port design.

When the flow of gasoline and oxygen is increased to a value at which the

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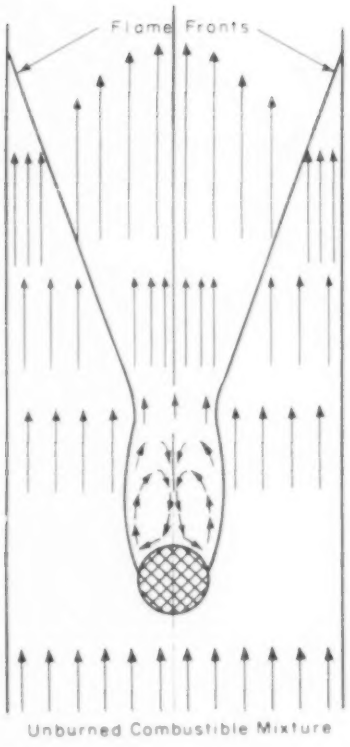


Fig. 1 Schematic representation of flame stabilization

Lengths of arrows correspond to relative local velocities (after Williams, Hottel and Scurlock[1])

exit velocity of the jet is greater than the speed of the combustion wave, the flame blows off. If the combustible mixture passes through a tube at a velocity less than some critical magnitude and if the tube diameter is sufficiently large, a flame may be caused to travel upstream. This is known as flash-back. If the tube is large, the critical velocity is approximately proportional to the tube diameter. This has been verified by Wohl, Kapp and Gazley.[2] As the diameter is decreased, however, it eventually becomes impossible for the flame to travel upstream even when the flow velocity is zero. In this case, the tube itself, which is at a relatively low temperature, absorbs heat from the stream, causing the temperature to fall below the ignition point. To date there is no satisfactory theoretical analysis of this quenching action, although the behavior of a flame near tube walls was studied by Kamenetsky.[3] Harris, Grumer, von Elbe, and Lewis[4] have reported quenching clearances between parallel plates, and compared these to quenching diameters for cylindrical ducts.

Williams,[5] with the evidence of high-speed Schlieren photographs of the blow-out process, has shown that blow-out is always preceded by turbulent decay of the flame, beginning downstream. At the blow-out condition, the ignition source can no longer propagate a flame front into the main body of the flowing mixture. Observation of the blow-out process shows that, as the limit is approached by increasing the oxygen flow rate, the flame front narrows, and finally the flame disappears.

One proposed method of flame propagation is based on the transfer of heat by conduction and the diffusion of atoms and free radicals ahead of the flame front. An approximate equation for flame velocity on this basis has been presented by Tanford and Pease,[6] and is consistent with measured flame velocities for a number of systems including hydrocarbons.

Williams, *et al.*,[7] derived the following expression for S_L, the laminar flame velocity:

$$S_L = \frac{K_i b \bar{\beta} (T_b - T_i)^2}{C_{pa} \rho_a^2 C_a (T_i - T_a)} \quad (1)$$

where

K_i = the thermal conductivity of the gas at T_i,
b = proportionality constant,
$\bar{\beta}$ = average rate of combustion reaction,
T_b = temperature of the burned gas,
T_i = ignition temperature of combustible gas,
C_{pa} = average heat capacity of the gas between T_a and T_i,
ρ_a = density of the unburned gas,
C_a = concentration of reacting material,
T_a = unburned stream temperature.

Equation (1) gives the following conclusions which have been verified experimentally:

1. Flame velocity increases with an increase in the thermal conductivity of the gas mixture.
2. Flame velocity increases with an increase in flame temperature and drops to zero when the flame temperature is as low as the ignition temperature.
3. Flame velocity decreases with an increase in the heat capacity of the unburned gas mixture.
4. Flame velocity increases with an increase of the temperature of the unburned gaseous stream.

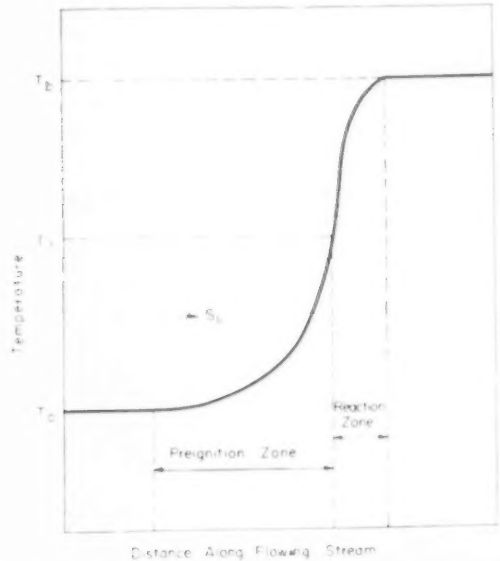


Fig. 2 Theoretical distribution of temperature near a moving flame front (after Williams, Hottel and Scurlock[1])

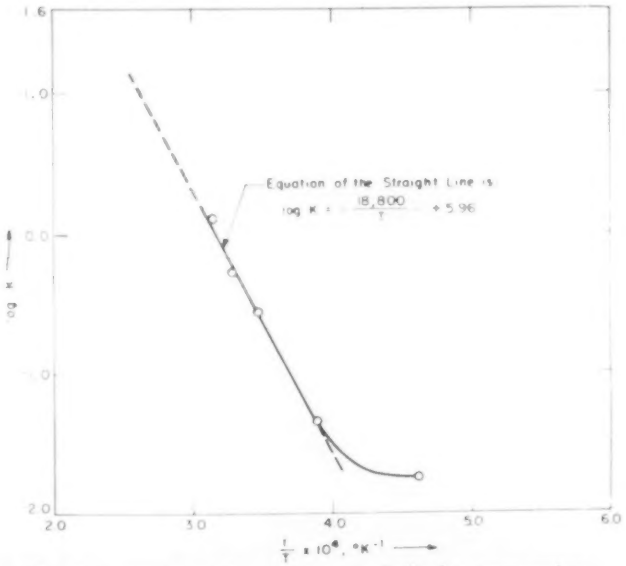


Fig. 3 Logarithm of K vs. reciprocal of absolute temperature

Heat transfer near a propagating flame front is represented schematically by the temperature distribution shown in Fig. 2.

Turbulence and chemical composition also influence the speed of flame propagation. Williams, *et al.*,[7] found that because turbulence accelerates heat transfer and momentum transfer rates, flame velocity also increases. Johnston[10] showed that the maximum flame velocity always occurs with a mixture that is slightly rich. The term "rich mixture" is used in the sense that there is not enough oxygen to burn the fuel completely to carbon dioxide and water vapor. In general, hydrocarbon fuels burn most rapidly with about 85 to 95% of the stoichiometric oxygen required for complete combustion.

Flame Temperature

Although, in oxygen cutting of low-alloy steel, the flame need only be intense enough to produce a "hot spot," well above the ignition temperature of iron (about 1800° F), competitive fuels are frequently compared in terms of flame temperature. Most often quoted are calculated adiabatic flame temperatures, obtained by dividing the heat evolved in combustion of a unit of fuel by the total heat capacity of the products of that combustion. In making such a computation, the composition of the products of combustion need be taken into account, before an accurate estimate can be made of the heat evolved. Frequently, calculations are based upon the convenient assumption that combustion is "complete" as possible, e.g., that a stoichiometrically balanced flame produces only CO_2 and H_2O, a "rich" flame contains no O_2, and a "lean" flame contains no H_2 or CO. The theoretical flame temperature so obtained will, in general, be too high, and the higher the temperature, the greater the error.

The temperatures involved in oxy-hydrocarbon flames used in cutting or welding are high enough to effect substantial dissociation of CO_2 and H_2O. In other words, carbon and hydrogen cannot be completely burned in a high temperature flame, so the heat evolved and temperature attained are less than if combustion were complete. The dissociation of CO_2 and H_2O computed at various temperatures from data of Lewis and von Elbe[1] is as follows:

Table 1

Temperature, °F	*% CO_2 dissociated*	*% H_2O dissociated*
2500	0.16	0.67
3500	1.8	1.57
4500	28.4	9.3

The calculation of flame temperature, taking cognizance of dissociation, has been treated by Jones, *et al.*[11] Bone and Townend[12] have proposed a technique for calculating the effect of radiation loss on flame temperature, and computed values are presented for various fuels. More recently Damköhler[13] outlined a more elaborate procedure for computation in which the formation of O, H and OH is considered. Sachsse and Bartholomé[14] have made extensive use of the method of Damköhler to compute flame temperature.

Table 2—Calculated Combustion Characteristics of Oxy-Hydrocarbon Flames[14]

Fuel	CH_4	C_2H_2	C_2H_4	C_3H_8
Moles of Fuel	1.00	1.00	1.00	1.00
Percent of Stoichiometric oxygen	100	100	90	100
Moles of Oxygen	2.00	2.50	11.25	12.50
$T_{max.}$, °F (with dis.)	4957	5492	5102	5084
$T_{max.}$, °F (without dis.)	9112	12,960	9362	10,372
	Products of Combustion			
Percent H_2O	37.19	8.86	26.11	25.62
Percent O_2	6.01	11.38	5.96	8.80
Percent O	3.26	10.44	3.93	4.62
Percent H	6.90	3.43	6.87	5.38
Percent CO	14.38	32.82	21.67	21.67
Percent OH	15.12	13.32	13.50	14.47
Percent CO_2	11.06	12.42	13.22	14.50
Percent H	4.58	7.33	5.74	4.93

Dissociation at high temperatures greatly complicates the calculation because the temperature and composition are interdependent. For example, consider combustion of one mole of n-octane with 90% of the stoichiometrically required oxygen:

$$11.250\,O_2 + C_8H_{18} \rightarrow \begin{cases} CO_2 \\ +CO \\ +H_2O \\ +H_2 \\ +O_2 \\ +O \\ +H \\ +OH \end{cases}$$

This equation cannot be immediately balanced since the number of moles of each product is unknown in addition to the temperature, the total number of moles and the partial pressure of each product. To solve for these eighteen unknown values, eighteen equations involving them are necessary. At high temperatures, the following dissociation reactions occur:

$$CO_2 \rightleftarrows CO + \tfrac{1}{2}O_2 \qquad (2)$$

$$H_2O \rightleftarrows H_2 + \tfrac{1}{2}O_2 \qquad (3)$$

$$H_2O \rightleftarrows \tfrac{1}{2}H_2 + OH \qquad (4)$$

$$\tfrac{1}{2}H_2 \rightleftarrows H \qquad (5)$$

$$\tfrac{1}{2}O_2 \rightleftarrows O \qquad (6)$$

For each of the above five equations, there is an equilibrium constant, K. For example, from Equation (2), $K = P_{CO}\sqrt{P_{O_2}}/P_{CO_2}$, where P_{CO}, P_{O_2} and P_{CO_2} are partial pressures of the indicated constituents.

Eight more relationships exist relating partial pressures to mole fractions. In the case of water vapor, $P_{H_2O} = N_{H_2O}/N_T$, where N_{H_2O} and N_T are the number of moles of water vapor and the total number of moles, respectively.

A fourteenth equation is supplied by the summation of the moles present: $N_{CO_2} + N_{CO} + \ldots\ldots = N_T$, where the N's again refer to the number of moles formed of each indicated constituent.

Separate material balances for oxygen, carbon and hydrogen provide three more relations. Finally, the eighteenth relation is a heat balance equating the heat content of the products of combustion to the sum of the heats of formation of the products less that of the reactants.

Using the method of Damköhler,[13] Sachsse and Bartholomé[14] have solved the above system of simultaneous equations, numerically, for many important fuels, and results of subject interest are summarized in Table 2. In particular it may be observed that significant portions of O, H and OH are to be expected in the hot part of the flame, and dissociation apparently prevents oxy-hydrocarbon flame temperatures from exceeding 5500° F. Maximum flame temperature is realized when slightly less than the stoichiometric amount of oxygen is used (also the condition for maximum flame velocity).

Careful scrutiny of the computed values leads to some useful general relationships. If the products of combustion undissociated are compared with the dissociated mixture, it is observed that dissociation is accompanied, on the average, by a 60% increase in volume of the gases taking part in the reaction. Considering the products of combustion as a single species, A, the composite dissociation equilibrium may be approximated by:

$$A_{1.6} \rightleftarrows 1.6A \qquad (7)$$

If a fraction, Y, of the products of combustion, dissociates in accordance with Eq. 7,

1 mole of $A_{1.6}$ becomes:

$$(1 - Y) \text{ moles of } A_{1.6} + 1.6\ Y \text{ moles of } A$$

and the total number of moles has increased from 1.0 to $(1.0 + 0.6\ Y)$. The equilibrium constant for Eq. 7 may then be written:

$$K = \frac{(1.6Y)^{1.6}}{(1.0 + 0.6Y)^{0.6}(1 - Y)} \quad (8)$$

The temperature rise which accompanies combustion is proportional to the heat evolved, and the heat evolved is, in turn, nearly proportional to the fraction of combustion products which remains undissociated:

$$1 - Y = \frac{T - T_i}{T_0 - T_i}$$

$$\text{or } Y = \frac{T_0 - T}{T_0 - T_i} \quad (9)$$

where T_0 is the flame temperature which would obtain in the absence of dissociation, T the flame temperature with dissociation, and T_i the initial temperature of the reactants.

Combining Equations 8 and 9, $\log K$ can be plotted vs. the reciprocal of the absolute temperature, using the results of Sachsse and Bartholomé.[14] The relationship, shown in Fig. 3 is linear except at temperatures so low that dissociation is unimportant, and all the results of Sachsse and Bartholomé are closely approximated by:

$$\log K = -\frac{18,800}{T} + 5.96 \quad (10)$$

where T is expressed in °K.

Equation 10 is also represented in Fig. 4, which constitutes a summary of results of Sachsse and Bartholomé. Using Fig. 4, the relatively simple calculation of T_0 may be used to arrive at a realistic flame temperature.

An Oxygen-Gasoline Cutting Torch

A brief study of the characteristics of a liquid-fuel cutting torch was conducted in an effort to apply existing general information on flames and combustion to modification and operation of a relatively untried, commercially available piece of equipment. The torch of conventional design but equipped to pressurize and meter liquid fuel, and to atomize and mix the fuel with oxygen, was subjected to a series of tests on flame stability, fuel-oxygen ratio and cutting rate. The torch and tip assembly are shown in Figs. 5 and 6.

Experimental Procedure

White, unleaded gasoline was used in all tests. Fuel flowed from a two-gallon container, maintained at 28 psig., to the torch at which a needle valve controlled the flow. The fuel flow rate was obtained by direct measurement before ignition using a graduated glass cylinder and stop watch. Upon adjustment of the fuel flow rate, preheat oxygen was supplied to give a lean mixture which was then ignited, following which, the oxygen flow rate was reduced to obtain the desired preheat flame.

Measurements of cutting velocity were made using ½-in. mild-steel plate. For each run, the flame core was adjusted to the proper position above the plate and the cut started. The speed was increased gradually until that speed was reached at which cutting became irregular, and the kerf ceased to be straight. After several confirmatory runs, the tank fuel valve was shut off, without the torch fuel valve being changed, and the preheat oxygen flow rate was measured. Finally, the tank fuel valve was re-opened and further series of cuts made using the same fuel flow rate but different oxygen flow rates. The entire procedure was repeated at different fuel flow rates.

Flame blow-off limits were established at various fuel flow rates by increasing the preheat oxygen flow until the flame was extinguished. Preheat flame ports with and without counter-bored holes were tried in an attempt to determine the effect of flame stabilizers on blow-off limits.

Using Schlieren photographs, limited observations were made of the supersonic flow of cutting oxygen from the tip of the torch.

Discussion of Results

Flame Stabilization. The general stability characteristics of the oxygen gasoline flame are typified by the relationship set forth in Fig. 7, which shows lean flame blow-off limits for the tip shown in Fig. 8*b*. It may be seen that stoichiometrically-balanced flames can be sustained only at low fuel flow rates; as the fuel flow rate increases, the stable flame becomes richer, being limited to much less than the stoichiometric amount of

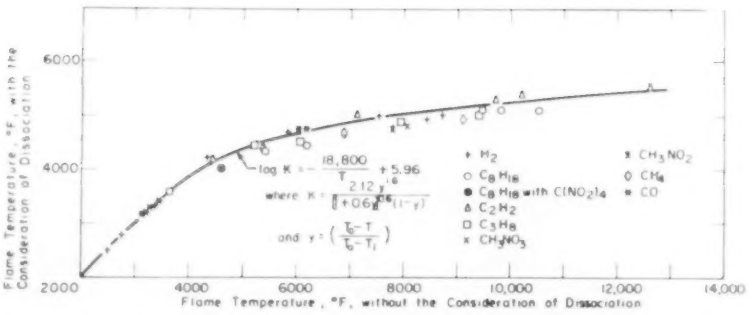


Fig. 4 The effect of dissociation on adiabatic flame temperature (data from Sachsse and Bartholomé[14])

Fig. 5 Oxygen-gasoline test model cutting torch

Fig. 6 Tip assembly

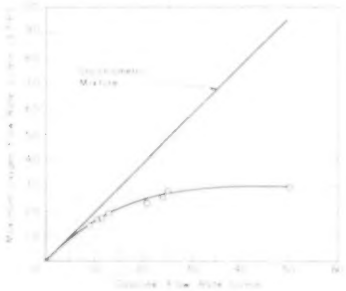
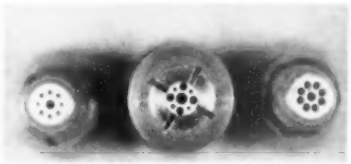


Fig. 7 Oxygen blow-off limits for oxygen-gasoline flames

For any fuel flow rate the curve gives the maximum oxygen flow which can be tolerated without blow-off



(a) (b) (c)

Fig. 8 Experimental tips

(a) "Standard" (b) Four ports counterbored, cutting oxygen nozzle contoured (convergent-divergent). (c) Eight ports counterbored

oxygen. However, as the combustible mixture becomes too rich, the counter-cyclonic effect embodied in the tip design (Fig. 6) fails to produce a finely atomized homogeneous mixture. Coarse particles of liquid gasoline flowing through the small preheat ports constantly vary the total cross-sectional area of the flow, introducing unsteadiness, and result in very rough burning. Several distinct types of flame were obtained by keeping the gasoline flow fixed and varying the preheat oxygen flow. The stable flame burned smoothly with practically no turbulence at the core. As the flame approached the blow-out limit, it became ragged and the shape of the core fluctuated violently.

In a conventional cutting tip, such as that shown in Fig. 8a, the flame ports are straight cylindrical ducts. It was found that modification by counter-boring of some or all of the flame ports (as shown in Figure 8b and 8c), so as to produce abrupt enlargement of the ports near the exit, increased flame stability. Counter-boring provided a small pilot region of turbulent eddy recirculation and low velocity for flame stabilization.

The Effect of Flame Composition on Cutting. Figure 9 presents the effect of the type of preheat flame on torch cutting speed. It can be seen that, for a fixed gasoline flow rate, the cutting speed actually increased with a decrease in preheat oxygen flow, i.e., a richer flame gave a higher cutting rate, in spite of the fact that the richer the flame, the lower the flame temperature. The data from which Fig. 9 was prepared are presented in Table 3.

In using a fuel-rich preheat flame to realize maximum cutting speed, it was observed, during the cutting process, that secondary combustion occurred at the cylindrical surface of the high-velocity cutting-oxygen stream, making this the hottest part of the flame, an effect clearly visible in Fig. 10. This secondary heat of combustion may, in accordance with the reasoning of Stoecker and Moen,[3] partly compensate the energy loss of the cutting stream due to kinetic effects, supply further heat to the cutting oxygen itself, or effectively preheat the steel in the immediate region of the kerf.

In addition, since maximum flame velocity is realized at approximately 90% of stoichiometric oxygen, the injection of cutting oxygen can locally stabilize a rich flame, rather than favor blowoff. The quality of cut was not materially influenced by the composition of the preheat flame, although the slag produced was more porous and friable, the more reducing the flame. Too rich a flame, however, was not hot enough to promote rapid ignition when cutting was initiated. All factors considered, operation appeared to be most favorable when the preheat flame contained about 50 percent of the oxygen required for "complete" combustion.

Table 3—Tabulation of Cutting Speeds

Steel Plate Thickness: 1/2 in.
Oxygen Line Pressure: 50 psig
Gasoline Tank Pressure: 28 psig

Gasoline flow rate, cc/min	*Preheat oxygen flow rate, l/min*	*Cutting oxygen flow rate, l/min*	*Cutting speed, in./min*	*Average, in./min*
12.0	6.18	42.2	32.5	
12.0	6.18	42.2	29.2	30.7
12.0	6.18	42.2	30.5	
12.0	9.6	42.2	25.5	
12.0	9.6	42.2	27.4	24.8
12.0	9.6	42.2	24.5	
12.0	12.0	42.2	19.5	
12.0	12.0	42.2	20.0	19.2
12.0	12.0	42.2	18.3	
16.1	19.3	41.7	13.0	
16.1	19.3	41.7	14.6	13.7
16.1	19.3	41.7	13.5	
16.1	16.0	41.7	16.0	
16.1	16.0	41.7	16.5	16.2
16.1	16.0	41.7	16.2	
16.1	11.9	41.7	20.5	
16.1	11.9	41.7	25.0	22.5
16.1	11.9	41.7	22.1	
16.1	7.1	41.7	28.6	
16.1	7.1	41.7	24.0	26.5
16.1	7.1	41.7	27.5	

Flow of Cutting Oxygen from the Torch Tip. Whatever preheat fuel is used, high velocity in the cutting-oxygen stream favors removal of reaction products and so facilitates cutting. That region of the jet which is supersonic can be observed by means of Schlieren photographs (Figs. 11, 12 and 13). Although supersonic exit flow of compressible gas from a jet is usually thought to require contoured (convergent-divergent) nozzles, the Schlieren photographs in Figs. 11 and 13 evidence supersonic flow from short, straight cylindrical nozzles. It was found, however, that a tip machined to approximate an ideal nozzle (Fig. 8b) produced a slightly longer supersonic region at a given oxygen pressure than did the corresponding cylindrical nozzle. This can be seen from careful comparison of Figs. 11 and 12.

In tests on cutting thick plate there was some indication the thickness which could satisfactorily be cut corresponded roughly to the length of the supersonic region of the jet, and further work to confirm this observation is in progress. The length of the supersonic jet from a

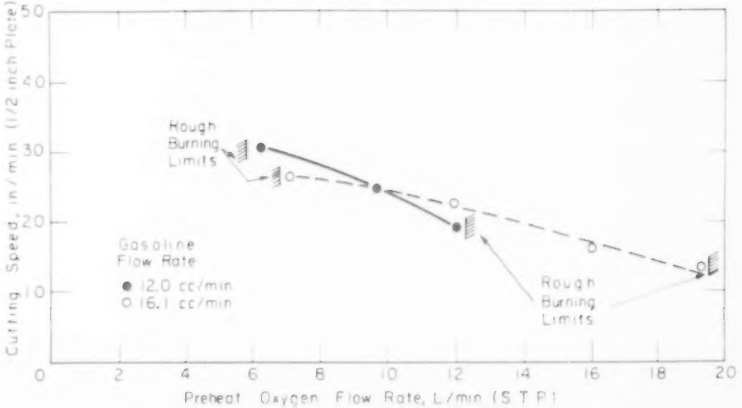
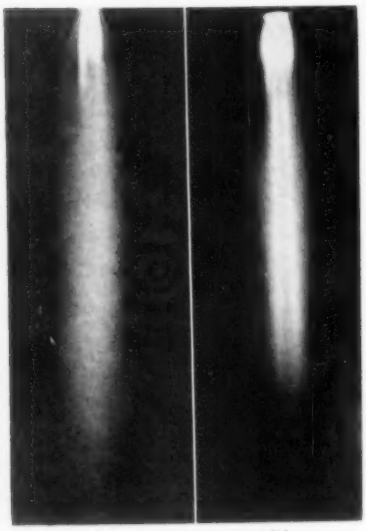


Fig. 9 Cutting speed as a function of flame composition



(a) (b)

Fig. 10 Influence of cutting oxygen on flame structure

Tip: Fig. 8 (b). Flow rate of gasoline: 16.5 cc/min. Preheat oxygen flow rate: 12.5 l/min. (a) Without oxygen cutting jet. (b) With oxygen cutting jet

cylindrical nozzle can be increased by (a) increasing the diameter of the nozzle, (b) increasing the pressure, or (c) contouring the nozzle. Use of contoured nozzles may prove of interest in cutting heavy plate with narrower kerfs and lower oxygen consumption.

Conclusions

1. A generalized relationship governing the effect of dissociation on adiabatic flame temperatures is derived, semi-empirically, from the extensive tabulations of Sachsse and Bartholomé. The relationship, presented graphically as well as analytically, permits calculation of a realistic adiabatic flame temperature for any oxy-hydrocarbon flame.

Maximum oxygen-hydrocarbon flame temperatures for most fuels lie between 4900 and 5500° F, and occur at oxygen-to-hydrocarbon ratios slightly less than stoichiometric.

2. Stoichiometrically balanced oxygen-gasoline flames can be sustained only at low fuel flow rates. At high fuel flow rates, only mixtures containing much less than the stoichiometric amount of oxygen will support a stable flame without blowoff.

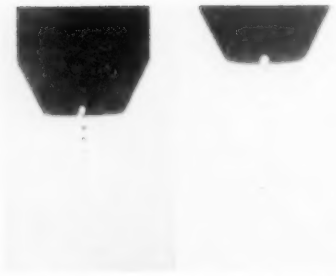


Fig. 11 Schlieren photographs of cutting-oxygen jet

Tip: Fig. 8 (a). (a) Pressure: 50 psig. (b) Pressure: 100 psig

(a) (b)

Fig. 12 Schlieren photographs of cutting-oxygen jet

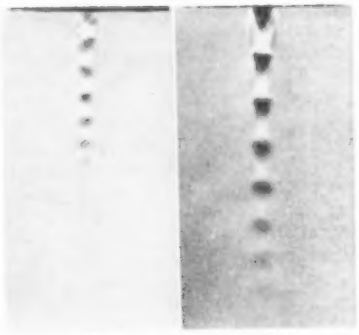
Tip: Fig. 8 (b), convergent-divergent nozzle. (a) Pressure: 50 psig. (b) Pressure. 100 psig

3. For a given fuel flow rate, the speed with which the oxy-gasoline torch can cut mild steel is inversely related to the flame oxygen flow rate (cutting oxygen flow rate being held constant). Rich flames surround the cutting oxygen stream with an intense "shell" flame, an effect associated with rapid cutting. In other words, the most efficient over-all use of oxygen is realized when part of the lance oxygen is used for combustion.

4. Supersonic flow of cutting oxygen is observed from cylindrical nozzles, is favored in convergent-divergent contoured nozzles and apparently bears some relationship to the effective cutting depth of the nozzle.

Acknowledgment

This investigation was supported in part through a Tau Beta Pi fellowship, and oxygen-gasoline cutting equipment was made available by the Worcester Taper Pin Co., Worcester 8, Mass.



(a) (b)

Fig. 13 Magnified Schlieren photographs of supersonic oxygen jet through a short cylindrical nozzle

Cylinder length/cylinder diameter = 1.50
(a) Pressure = 40 psig. (b) Pressure = 75 psig

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EVALUATION OF THE KINZEL TEST FROM ITS FRACTURE CHARACTERISTICS

Paper relates the observed effects of plate composition, welding conditions and heat treatment on transition temperature to the changes in the ability of the various regions at or near the weld to initiate or resist cleavage fracture. Limitations of Kinzel test are also discussed

BY R. D. STOUT, W. J. MURPHY AND R. C. WESTGREN

FOREWORD. The investigation reported here was conducted for the Weldability Committee of the Welding Research Council with the support of the American Iron and Steel Institute. The authors are grateful for the guidance and support of these organizations.

Introduction

In a previous paper[1] a technique was described for studying the contributions of the various microstructures in the region of the weld to the fracture of Kinzel-test specimens over their transition-temperature range. It was shown that the transition temperature of welded-steel specimens (determined by a level of 1% lateral contraction) lies between the lower limit of the transition of unwelded-steel specimens and the upper limit of temperature above which the base metal cannot be forced to fail by propagation of a cleavage fracture. The precise location of the transition temperature between these limits is controlled by the tendency of some region in the vicinity of the weld to initiate a running cleavage crack.

In the present investigation it was intended to relate the observed effects of plate composition, welding conditions and heat treatment on transition temperature to the changes in the ability of the various regions at or near the weld to initiate or resist cleavage fracture. For example, what changes in the weld heat-affected zone help to explain the toughening effect of postheating? A second aspect of the investigation was concerned with the limitations of the Kinzel test as a means for evaluating the influence of welding on notch toughness.

Terminology

For convenience, the term *weld zone* will be used to designate as an entity the weld metal and the heat-affected zone adjacent to it. The weld zone will be divided arbitrarily for discussion into four regions, even though these merge gradually one into the other in actuality. The fused area will, of course, be called *weld metal*. The area just below the fusion line will be called *coarse-grained zone*; the portion heated into the normal heat-treating range, the *refined zone*; the region heated between A_3 and A_1, the *intercritical zone*.

Materials and Specimen Preparation

The steels used in this investigation were supplied as 1-in. thick plates. Their compositions, tensile properties and as-received conditions are given in Table 1.

Kinzel-type specimens 3- by 18-in. were cut with the longitudinal axis parallel to the rolling direction. Longitudinal weld beads were deposited automatically with $^5/_{32}$-in. electrodes at a travel speed of either 6 or 10 ipm and at 24 volts and 180 amp. Specimens which were preheated were controlled to +25–0° F with temperature crayons and were allowed to cool naturally to room temperature after welding.

After welding, the specimens were notched transversely with a Charpy V-notch cutter to a depth of 0.050 in. at locations 6 in. from either end and aged 7 days between welding and testing.

The bend specimens were tested on a standard 11-in. span with a loading rate of 2-ipm head movement on the hydraulic machine. Each specimen was measured at the notch root before and after testing for lateral contraction. The fracture pattern of each specimen

Table 1—Characteristics of Steels Used for Testing Chemical Analyses (in Percent)

Steel grade	*Code*	*C*	*Mn*	*P*	*S*	*Si*	*Ni*	*Cr*	*Mo*	*Other*
A285 Gr. B	BY	0.16	0.45	0.010	0.024	tr.				
A201 Gr. A	EY	0.14	0.51	0.014	0.033	0.20				
A212 Gr. B	KC	0.25	0.66	0.020	0.022	0.19				
A212 Gr. B	GY	0.27	0.69	0.010	0.028	0.24				
4S-5-HT	NB	0.15	1.10	0.026	0.040	0.23	0.12			0.19 Cu 0.03 Ti
A203 Gr. D	CY	0.13	0.60	0.022	0.032	0.22	3.40			
A302 Gr. B		0.19	1.26	0.018	0.025	0.22			0.46	
A387 Gr. D	SY	0.09	0.44	0.013	0.011	0.25		2.18	0.96	
A357	OY	0.06	0.50	0.019	0.022	0.34	0.13	4.96	0.55	

Tensile Properties as Received

Steel	*Condition*	*0.2% offset yield strength*	*Ultimate strength*	*Elongation in 2 in.*
A285	As-rolled	40,000 psi	59,900 psi	27.5%
A201	As-rolled	37,800	59,800	31 (in 8 in.)
A212(KC)	As-rolled	36,400	74,700	31.7
A212(GY)	As-rolled	47,600	81,200	25.5
4S-5	Mill-normalized	44,500	70,500	28.0
A203	As-rolled	45,500	77,600	25.5 (in 8 in.)
A302	As-rolled	72,400	97,000	21
A387	Annealed	39,400	67,800	33.7
A357	Annealed	38,000	66,200	34

R. D. Stout is associated with Lehigh University, Bethlehem, Pa., W. J. Murphy is in private business in Boston, Mass., and R. C. Westgren is associated with the Westinghouse Electric Corp., Pittsburgh, Pa.

Table 2—Summary of Results

Steel A285 Grade B (Code BY)

Steel condition	Welding conditions: Electrode	Amp	Travel in./min	T_c, Lateral contraction transition temperature, °F	Locus of crack initiation	Locus of crack arrest
As-rolled	E6010	180	6	+65	Coarse grains and weld metal	Base metal and refined heat-affected zone
As-rolled	E6010	180	10	+55	Coarse grains	
As-rolled	E6010	180	6 in./min + 1150 °F postheat	−35	Coarse grains	

Steel A201 Grade A (Code EY)

Steel condition	Welding conditions: Electrode	Amp	Travel	Other	T_c, Lateral contraction transition temperature, °F	Locus of crack start	Locus of crack arrest
As-rolled	E7015	180	6		−30	Coarse grains	None or base metal
As-rolled	E7015	180	6	400° F preheat	−40	Weld metal and coarse grains	
As-rolled	E6010	180	6		+20	Weld metal and coarse grains	Base metal or refined heat-affected zone
As-rolled	E6010	180	10		+10	Weld metal and coarse grains	Base metal or refined heat-affected zone
As-rolled	E6010	180	6	1150° F postheat	−35	Coarse grains	
Prenormalized	E6010	180	6		+10	Weld metal and coarse grains	Base metal and refined heat-affected zone
As-rolled	E310	180	6		−5	Coarse grains	

Steel A203 Grade D (Code CY)

As-rolled	E6010	180	6		+40	Intercritical	Refined heat-affected zone
As-rolled	E6010	180	6	1150° F postheat	−175	Weld metal	Refined heat-affected zone
As-rolled	E9015	180	6		+10	Intercritical	Or base metal
As-rolled	E9015	180	6	1150° F post-heat	−135	Weld metal and coarse grains	Refined heat-affected zone
As-rolled	E9015	180	10		+15	Intercritical	Base plate
Prenormalized	E9015	180	6		−70	Coarse grains and intercritical	Refined heat-affected zone and base metal

Steel 4815-HT (Code NB)

As-rolled	E6010	180	6		+25	Weld metal and intercritical	Refined heat-affected zone
As-rolled	E6010	180	6	1150° F post-heat	−40	Weld metal and coarse grains	
As-rolled	E6010	180	10		+35	Intercritical	Base metal
As-rolled	E310	180	5		+20	Intercritical	

Steel A302 Grade B (Code TY)

Mill-normalized	E9015	180	6		25	Intercritical	Base metal
Mill-normalized	E9015	180	6	400° F preheat	25	(Weld metal, coarse grains) and intercritical	Base metal
Mill-normalized	E310	180	6		30	Intercritical	Base metal

Steel A212 Grade B (Code KC)

As-rolled	E6010	180	6		+25	Weld metal and coarse grains	Base metal
As-rolled	E6010	180	10		+50	Weld metal and coarse grains	Base metal
As-rolled	E6010	180	6	1150° F postheat	−65	Weld metal and coarse grains	
Prenormalized	E6010	180	6		+5	Weld metal or coarse grains	Base metal
As-rolled	E6010	180	6	Double pass	−10	Coarse grains	

Steel A212 Grade B (Code GY)

As-rolled	E7015	180	6		+45	Weld metal and coarse grains	Base metal and refined heat-affected zone
As-rolled	E7015	180	6	400° F preheat	+45	Weld metal and coarse grains	Refined heat-affected zone
As-rolled	E7015	180	10		+60	Weld metal and coarse grains	
As-rolled	E7015	180	10	400° F preheat	+25	Weld metal and coarse grains	
As-rolled	E310	180	6		+60	Intercritical and coarse grains	
As-rolled	E310	180	6	400° F preheat	+20	Coarse grains and intercritical	

Table 2—Summary of Results (Contd.)

Steel condition	Electrode	Welding conditions: Travel (amp, in./min)		Other	1% Lateral contraction transition temperature, °F	Locus of crack start	Locus of crack arrest
				Steel A357 (Code OY)			
Annealed	E502-15	180	6		−40 to −10	Weld metal and coarse grains	Base metal
Annealed	E502-15	180	6	600° F preheat	−10	Weld metal and coarse grains	Base metal
Annealed	E502-15	180	6	1350° F post-heat	−20	Coarse grains	Base metal
Annealed	E502-15	180	6	600° F preheat 1350° F	−20	Coarse grains	
				Steel A387 Grade D (Code SY)			
Annealed	E9015-B3	180	6		−5	Weld metal and coarse grains	Base metal
Annealed	E9015-B3	180	6	Preheat	+20 to −10	Weld metal and coarse grains	Base metal
Annealed	E9015-B3	180	10		+15	Weld metal and coarse grains	Base metal
Annealed	E9015-B3	180	10	600° F preheat	+10	Weld metal and coarse grains	

was analyzed both macroscopically and microscopically and recorded by sketches.

In addition to the welds prepared with E6010 or the grade of low-hydrogen electrode appropriate to each steel, spot-check welds of austenitic stainless steel, E310, were included for several of the steels. These welds provided a tough weld metal to be substituted in test series where the brittleness of the ferritic weld metal appeared to influence the fracture pattern.

The Experimental Results

Essentially the experimental program consisted of observing the response of a fairly wide variety of carbon and low-alloy steels to variations in the welding-heat input, the plate temperature during welding and postheat treatments. Attention was centered on the behavior of each portion of the weld zone as revealed by the fracture patterns studied over the complete ductility-transition range.

The results are summarized in Table 2. For each steel are indicated the welding conditions, the 1% lateral contraction temperature, the specific origin of cleavage fracture and the structure in the specimen which first arrested cleavage, if any did so. Analysis and discussion of the results follow in the next section.

Discussion of Results

Before taking up discussion of the results reported here, it may be helpful to recall the general mechanism by which welding influences the tendency of steel to brittle fracture. First, the weld joint may furnish stress raisers in the form of internal faults, undercutting, weld ripples and the like. Second, the metallurgical changes introduced by the welding thermal cycle may produce areas in the weld vicinity of low notch toughness. The longitudinal bead notch-bend specimen is intended to reproduce these weld thermal-cycle conditions so that the variables of steel and welding conditions can be assessed as to their influence on welded notch toughness. While in general the test has been shown to furnish useful information, some anomalies in behavior have become apparent which will be described later.

Examination of fracture patterns has established that the controlling areas in the weld zone can be divided roughly into the following categories: weld metal, coarse-grained heat-affected zone, fine-grained heat-affected zone, inter-critical (or inter-transformation) zone heated between A_1 and A_3, and unaffected base metal. In the absence of welding, the bend test shows low transition temperatures (−50 to −150° F) at 1% lateral contraction for structural steels. Introduction of a weld bead raises the transition temperature 50 to 200° F because of a triggering action of some part of the weld zone which more readily initiates cleavage failure. The weld zone acts as a trigger because it contains structures which are more notch sensitive than the original base metal. Therefore, the optimum welding condition is that which minimizes the embrittlement of the weld zone.

Data have been abstracted from Table 2 for more convenient analysis of the effect of welding conditions on transition temperature as indicated by the Kinzel test. The manner in which the various regions around the weld participate in the production of brittle failures in the various steel types is discussed subsequently.

Effect of Heat Input, Preheat and Postheat

The table below compares the transition temperatures for 6- and 10-ipm travel speed, the two levels of heat input that were investigated:

Effect of Heat Input on Transition Temperature

Steel	Transition temperature for 6 in./min, °F	Transition temperature for 10 in./min, °F
A 285	+65	+55
A 201	+20	+10
A 212 (KC)	+25	+50
A 212 (GY)	+45	+60
A 203	+10	+15
18s 5	+25	+35
A 387	−5	+15

On the whole, the effect of heat input is small. One would expect the low-carbon A285 and A201 to be insensitive to heat input as was observed. The higher carbon A212 heats are slightly more embrittled by the faster cooling rate at 10 ipm. The alloy steels change little in transition temperature with travel speed, possibly because they have low-carbon content and enough hardenability to respond similarly at both heat inputs, i.e., both welding speeds produce the same types of microstructures in the

weld zone.

The effect of preheating is shown in the following table for a number of the steels:

Effect of Preheating on Transition Temperature

Steel and travel speed	Welded at R.T., °F	Welded at temperature stated, °F
A201 6 in./min	−30	−40 (400° F)
A212 6 in./min	+45	+45 (400° F)
10 in./min	+60	+25 (400° F)
A302 6 in./min	+25	+25 (400° F)
A357 6 in./min	−20	−10 (600° F)
A387 6 in./min	− 5	+20 to 40 (600° F)
10 in./min	+45	+10 (600° F)

The Kinzel test does not indicate any benefit from preheating. There are two cases of a 10–40° F increase in transition from preheating, which are discussed later. Now it must be emphasized that in fabrication of weldments, preheating is an invaluable technique for reducing the incidence of cracks and thus improving the service properties of the weldment. The microstructural benefit of preheating to notch toughness is somewhat less certain. In the Columbia beam tests,[2] preheating to 400° F improved two carbon steels only 10 to 20° F. A recent study by Kennedy[3] indicated no improvement in the toughness of butt-welded 3-ft-wide plates of mild steel due to preheating at 400° F. The low-alloy steels did not appear by microscopic examination to form a more favorable structure in the coarse-grained region when preheated than the low-carbon martensite produced by room-temperature welding.

The data for A357 and A387 steels indicate spuriously an adverse effect of preheating. Careful study of this problem has exposed a characteristic of the Kinzel test which was only partially appreciated before. If failure of a brittle portion of the weld zone occurs very early in the bending of the specimen, the elastic energy stored in the specimen and testing machine is insufficient to propagate cleavage through the steel section even though the testing temperature is favorable. Unloading occurs and the cracking reverts to shear temporarily. A tougher weld zone allows higher loading before failure and through cleavage is possible. Thus, the very brittle weld zone requires lower temperatures for complete cleavage than the tougher weld zone. This effect of load level is shown in Fig. 1 where the crosses indicate the load level for complete cleavage and the circles the load reached by specimens in which cleavage was interrupted. Higher loads consistently are associated with through-cleavage failure.

A few tests run previously had hinted at this phenomenon. A high-hardness hard-surfacing electrode was used for the weld bead in a series of Kinzel specimens. The transition temperature was slightly lower for this series than for a parallel series welded with E7015.

In order to clarify this point, additional series of Kinzel specimens of A357 were welded at 6 ipm, one at room temperature, one preheated to 600° F and one welded at room temperature and postheated to 1350° F. The specimens were tested on the drop-weight machine to provide an excess of breaking energy. The results are tabulated below.

Comparison of Static and Drop-Weight Kinzel Tests

Condition	Static transition temperature, °F	Drop-weight transition temperature, °F
Welded at RT	−10 to −10	20
Welded at 600° F	−10	10
Welded at RT, 1350° F postheat	−20	0

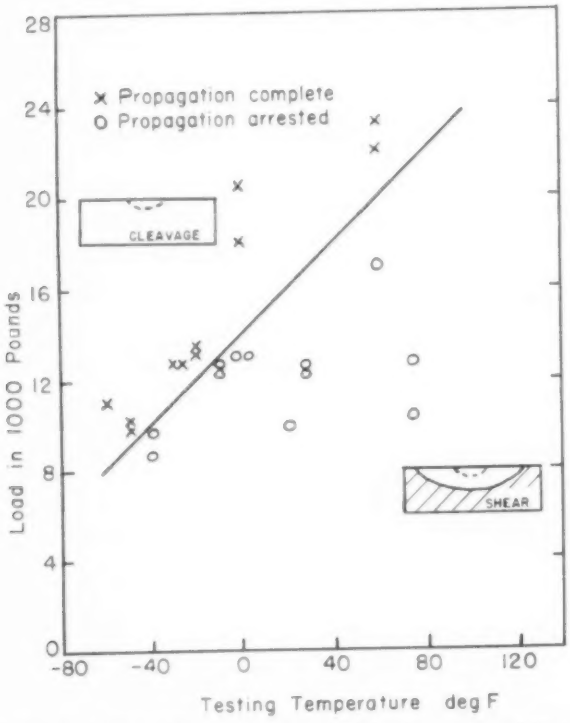

Fig. 1 Effect of load at the time of initiation on the ability of the base metal to interrupt cleavage-crack propagation. A357 steel

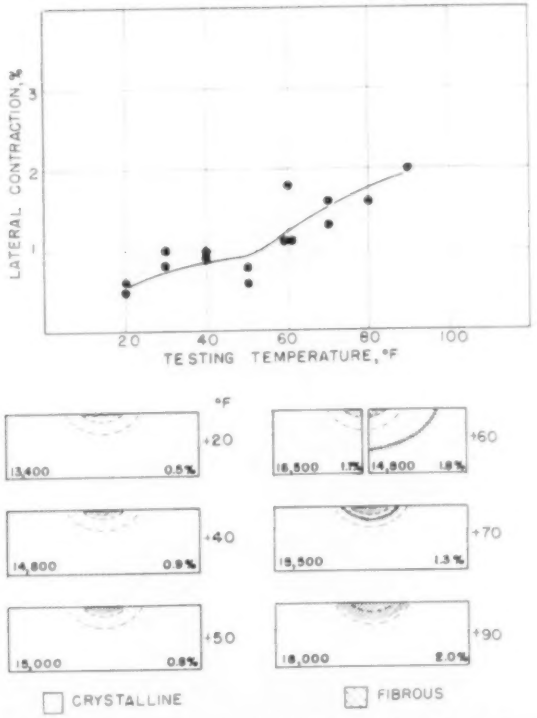

Fig. 2 Kinzel transitional behavior and fracture patterns for A285 steel welded with $\frac{3}{16}$-in. E6010 at 6 ipm

The drop-weight Kinzels show less difference between the room-temperature and 600° F series. The postheated series became the best of the three when tested dynamically.

Postheating has generally been found to be beneficial in Kinzel tests of carbon and low-alloy steels. Below are summary data on the effect of postheating.

Effect of Postheating on Transition Temperatures of Welded Steel

Steel	As-welded, °F	As-postheated, °F	Postheat temperature, °F
A285	+65	−35	(1150)
A212 (KC)	+25	−65	(1150)
A203 (E6010 electrode)	+40	−175	(1150)
A203 (E2015 electrode)	+40	−135	(1150)
1885	+25	−40	(1150)
A357 (600° F preheat)	+10	−20	(1350)

Except for A357, the improvement with postheating is obvious. The Kinzel test probably exaggerates the importance of postheating* relative to multipass welding where the heat of subsequent passes acts to improve the weld zones beneath them.

Fracture Behavior in the Kinzel Test

According to Table 2, the source of brittle failure varies with the steel and the welding conditions. Typical transition curves and fracture patterns are shown in Figs. 2 to 6 for carbon and low-alloy steels. In the carbon steels, initiation of the cleavage crack is consistently in the coarse-grained heated zone and weld metal. In the alloy structural steels, initiation occurs in the intercritical zone in as-welded series but switches to the coarse-grained area upon postheating. The Cr-Mo steels fail first in the coarse grains and weld metal.

In most cases the weld metal and coarse grains are indicated together as the source of failure. This is done because the fracture patterns do not single out one of the two as the crack source. However, supplementary tests with E310 austenite deposits suggest that the coarse-grained area may well be chiefly responsible. Little change in transition temperature is noted with the tougher weld metal, whose shear behavior does not alter the cleavage tendency of the coarse grains. This is also true for steels displaying failure at the intercritical zone. If the tough austenitic weld replaces a brittle weld metal, the transition temperature may actually be raised slightly by the effect of the higher load at crack initiation described previously.

In carbon steels both the base metal and the refined-grain zone serve to arrest cleavage cracks at the 1% lateral contraction level. In the alloy steels, more commonly the base metal is alone available to arrest cracking, necessarily so with intercritical zone initiation. In postheated series, usually the ductility displayed during initial shearing provides the lateral contraction, and later cleavage proceeds uninterrupted.

A broad picture of the fracture behavior of longitudinal bead notch-bend test specimens can be attempted as follows. In the absence of welding, the notched-bend specimen fails at a level of 1% lateral contraction only at relatively low temperatures, low enough to favor early cleavage initiation from the shear crack which always forms first. Welding raises the transition temperature by creating zones in its vicinity that more readily generate cleavage cracking. The resulting transition temperature will be located as the highest temperature at which an area of the weld can initiate a cleavage crack, which in

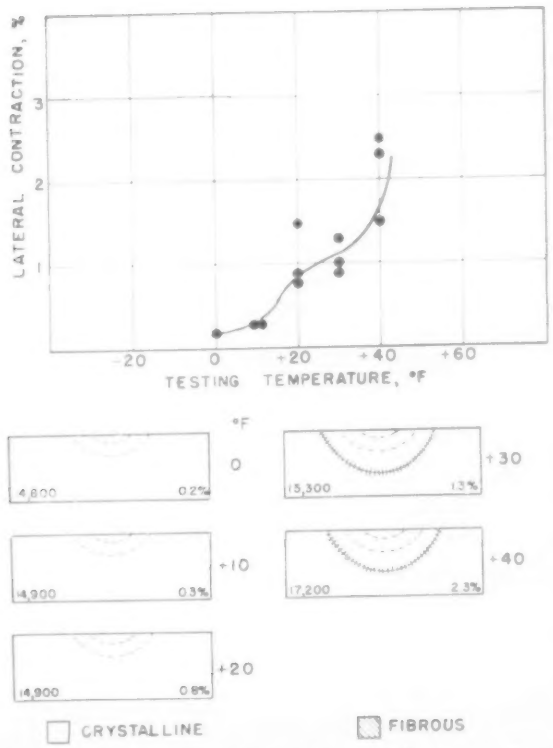

Fig. 3 Kinzel transitional behavior and fracture patterns for A212 steel welded with 3/16-in. E6010 at 6 ipm

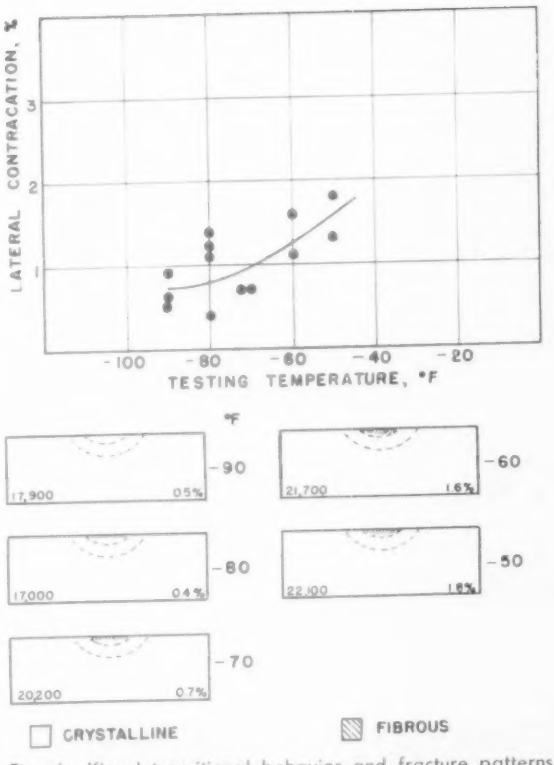

Fig. 4 Kinzel transitional behavior and fracture patterns for A212 steel welded with 3/16-in. E6010 at 6 ipm and postheated 1 hr at 1150° F

turn cannot be arrested by the base metal—or by the refined-grain region when it is in a position to act. Thus, two requirements must be met to have brittle failure (less than 1% lateral contraction) in the Kinzel test. The temperature must be low enough to permit some zone to trigger cleavage, and it must be low enough to have the remaining steel section accept the cleavage. If this is so, the performance of welded steel can be improved by toughening either the critical weld zone or the base plate. Postheating acts on the first factor, while normalizing before welding affects mainly the second. Preheating and heat input to the weld can influence transition temperature only by their action on the triggering zone. Since they may alter its microstructure favorably or unfavorably according to the steel, it is not surprising to find them unreliable as means of improving notch toughness.

Summary of the Contribution of the Weld Zone to Brittle Fracture

In the Kinzel test, the weld metal seldom exerts a noticeable influence on test results. It is small in volume and surrounded by the coarse grains which are usually more brittle than the weld metal. Thus, even austenitic weld metal has little or no effect on transition temperature.

In carbon steels the coarse-grained area is the chief source of cleavage failure. The large grain size and the aggregates of hard pearlite and or martensite enveloped in weak ferrite are a particularly notch-sensitive combination. In low-alloy steels such as 4855, A203 and A302, welding may produce all-martensite coarse grains which are considerably tougher and hence do not initiate cleavage.

The refined zone would serve as an effective crack arrester if it were larger in volume. Nevertheless, it often converts the cleavage crack to shear temporarily and allows the lateral contraction to reach 1%.

The intercritical zone is active as an initiation site for cleavage in both carbon and alloy steels. If the refined zone stops cleavage, the intercritical zone usually reactivates it when the crack reaches that region. The notch sensitivity of the intercritical zone is due to the hard areas of martensite or fine pearlite formed within the soft ferrite matrix during partial transformation.

Optimum Welding Conditions for Notch Toughness

Apart from welding, the inherent toughness of the steel to be welded will naturally be a prime factor in its performance as a weldment. For a given steel, the welding conditions can be chosen to minimize the danger of brittle failure. Favorable geometrical features must be sought by proper design and fabrication free from cracks, incomplete fusion and undercutting. Preheating often assists in obtaining sound welded joints. On a metallurgical basis, there are two procedures that are beneficial. One is to adjust the size of successive passes to produce maximum refinement of the weld and base metals underneath. Generally a larger number of smaller beads is beneficial to both weld and base-metal toughness. The second is to use postheating where feasible. Both tempering and stress relief are provided by over-all postheating, but localized heating to temper only should enhance the toughness of the weldment. Preheating appears to be of doubtful assistance to the microstructural properties of most structural steels.

Limitations of the Kinzel Test

The Kinzel test has previously been employed to furnish useful information about the effects of welding, of heat treatment and of base-metal characteristics on the notch toughness of steel. In the main, the conclusions reached appear to be valid. During the investigation, however, several peculiarities

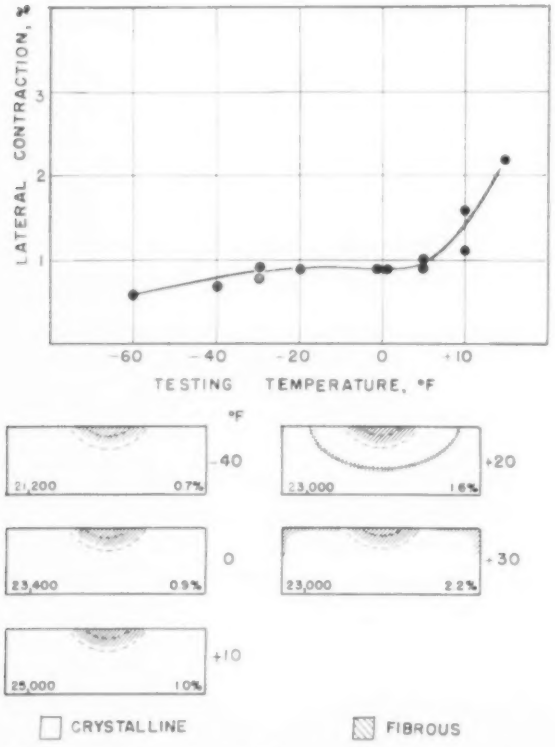

Fig. 5 Kinzel transitional behavior and fracture patterns for A203 steel welded with $^{3}/_{16}$-in. E9015 at 6 ipm

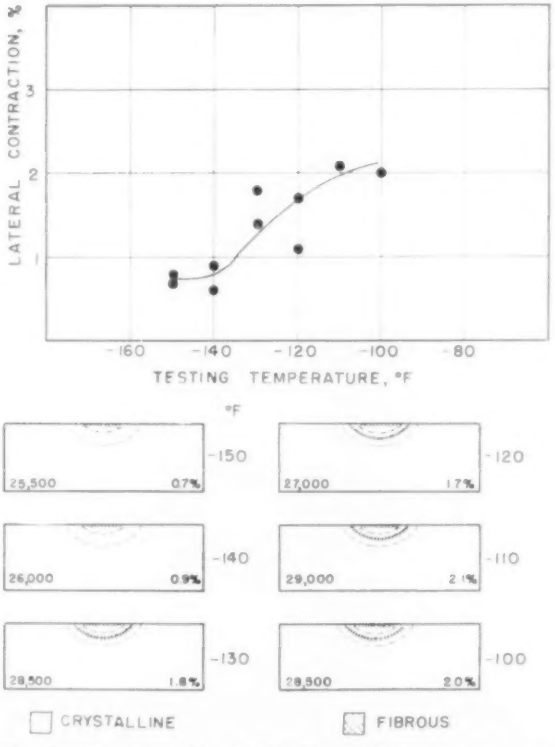

Fig. 6 Kinzel transitional behavior and fracture patterns for A203 steel welded with $^{3}/_{16}$-in. E9015 at 6 ipm and postheated 1 hr at 1150° F

of the test have been demonstrated by test work to lead to questionable conclusions.

One peculiarity of the test mentioned earlier is the effect of early failure in cleavage of a weld zone while the load and stored energy on the specimen are low. This behavior is not new or unique to the Kinzel test. If excessively-brittle hard-surfacing deposits are used for the drop-weight specimen, a similar result is obtained. Further work is planned to learn whether this difficulty can be overcome conveniently. It is easy to detect the occurrence of premature unloading during the testing operation by the audible clicks and momentary unloading. If these occur before the specimen yields slightly plastically, there is probably a disturbing unloading taking place.

A second area of doubt is the part played by the changes in dimensions of the weld zone due to preheating or heat-input changes. If a larger volume of a triggering region in the weld is exposed to the notch, it may affect the transition temperature. While a comparable shift in dimensions would be obtained in actual welded joints, it is doubtful that the effect would be the same in the joint and in the test specimen. It has been the practice in this laboratory to compensate for obvious decreases in depth of penetration by pregrooving the plate before depositing the weld metal. If the specified 6-ipm travel with the common electrodes is used, this factor is probably of little concern.

Summary

The results of this investigation can be summarized as follows:

1. Welding raises the ductility transition of steel, as measured by a longitudinal-bead notch-bend test such as the Kinzel test, by producing a trigger for cleavage-crack initiation in the vicinity of the weld.

2. The two locations in the weld zone which act as triggers in most steels are the coarse-grained region and the intercritical region (which is heated between the A_c and A_1 temperatures).

3. In the carbon steels tested, the coarse-grained region was usually the source of the cleavage cracks. In low-alloy steels, initiation more commonly occurred in the intercritical zone.

4. As measured by the Kinzel test, preheating and the heat-input level were not effective in changing the transition temperature of the carbon or low-alloy steels tested in this investigation.

5. In Kinzel tests, postheating restored much of the notch toughness lost by welding.

6. The Kinzel test has been observed to be sensitive to the loading level at the instant of cleavage initiation. If a highly-brittle area initiates cleavage very early in loading, the cleavage is readily converted to shear by adjacent areas, and additional deformation occurs. In effect, a lower transition temperature results. The size of the weld-affected zone as controlled by heat input and preheat may also exert a geometrical effect on the fracture characteristics of the specimen.

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THE EFFECT OF DEFECTS ON THE FATIGUE STRENGTH OF SUBMERGED-ARC WELDS

BY H. MÖLLER AND M. HEMPEL

Abstract by G. E. Claussen of "Beitrag zur Bewertung von Schweissfehlern auf Grund von Röntgenaufnahmen und Zugschwellversuchen an Geschweissten Proben," published in Archiv für das Eisenhüttenwesen, 28, 531–541 (1957)

The tests described in this report were made to estimate the influence of common welding defects, as revealed by radiography, on the fatigue strength of submerged-arc welds made under plant conditions. The literature (see Bibliography given herewith) shows that small defects had little effect on strength, but most of the work was done on steel plates less than ¾ in. thick. The present tests were made on plates up to 4 in. thick at the Max-Planck-Institute, Table 1 (page 128-s). The pulsating tension fatigue tests were made on an oil hydraulic pulsator using specimens ¾ in. x plate thickness in cross section, machined on all sides. The weld was perpendicular to the axis of stress. The lower stress was two-thirds of the yield strength. The upper stress for the first 2,000,000 cycles was 7000 psi above the lower. If the specimen did not fail, the upper stress was raised another 7000 psi for 2,000,000 cycles, and so on in steps of 7000 psi until failure occurred. The higher the number of steps before failure, the higher the quality of the specimen.

The results in the last column of Table 1 show that incomplete fusion or poor penetration lowered the fatigue strength considerably, compared with the specimens without defects. Specimens with isolated blowholes and groups of small holes or slag inclusions had good fatigue strength. Laminated plate also did not lower the fatigue strength.

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(Continued on page 128-s)

CONTROLLED LOW-TEMPERATURE HOT ROLLING AS PRACTICED IN EUROPE

Memorandum describes the low-temperature hot-rolling techniques being used by some mills in Europe to obtain increased notch toughness

BY R. W. VANDERBECK

ABSTRACT. Controlled low-temperature hot rolling is being practiced by some mills in Europe to provide increased notch toughness in hot-rolled plate product. The practice involves making the last several hot-rolling passes at lower-than-normal temperatures so that the final finishing pass is below about 1600° F and may be as low as 1360° F, depending upon the particular controlled rolling technique that is used. An average improvement in the 15 ft-lb V-notch Charpy transition temperature of 20 to 45° F seems to be possible by the use of such a practice.

Introduction

A number of steel mills in Europe are practicing controlled low-temperature hot rolling for some of their plate production for the specific purpose of providing material with increased notch toughness. Before discussing the benefits of such practice, however, it would be well to mention briefly how the method of specifying a steel may have a distinct bearing on the problem of providing material with the desired notch toughness characteristics.

In plates for structural applications where notch toughness is known to be an important consideration, as for example in ships, it is becoming the practice in Europe to require certain minimum impact properties in the plate product. These properties are not necessarily required on every plate but only, for example, on the thickest plate from a lot of about 25 tons. The emphasis is on the properties of the final plate product, and steelmaking practice and composition are not always rigidly defined. To a great extent, this is due to the greater variety of steelmaking practices that are prevalent on the European continent. The trend is therefore to give the steelmaker considerable leeway in making his steel, just so long as the desired properties are obtained in the final product.

In the United States, the situation is different at present. For structural applications such as ships, the steel is not ordered to impact properties. Instead, the steelmaking practice and composition (plus tensile properties) are defined within narrow limits. It is fairly well known, however, what impact properties may be expected from steels made in this manner.

In Europe, therefore, there is some incentive for trying to find the most economical way of obtaining the desired notch toughness through adjustments of composition and processing variables, and controlled low-temperature hot rolling is one such method that is being used. This process admittedly slows down the production rate, but the extent to which it does will vary with the particular mill setup. To determine the economy of such a technique, the reduced production rate would have to be weighed against alternative methods of producing a steel of comparable quality. Also, the production level would probably be an important consideration. If production schedules were not full, a decreased rate of production would probably not be as undesirable as it would be if a mill were operating at full capacity. In any event, some mills in Europe are using the low-temperature hot-rolling technique.

Dutch and Belgian Hot-Rolling Practices

In recent discussions with Dr. J. H. van der Veen, Supt. of Quality Control of the Royal Netherlands Blast Furnace and Steelworks, Ltd., in Holland, a considerable amount of data was obtained regarding low-temperature rolling practice. Their experiments have indicated that an appreciable lowering of transition temperature can be obtained by making the last several rolling passes at lower-than-normal temperatures. The optimum temperature for the last pass is just above the Ar_3. The optimum number of passes at reduced temperatures and the optimum amounts of reduction (the two may be interdependent) do not seem to be well established, but it does seem certain that several such passes provide a greater improvement than a single pass. (This has also been verified in hot-rolling studies reported by Lightner and Vanderbeck.*)

Royal Netherlands' present procedure for this type of rolling is to perform the initial rolling in the usual manner until the slab reaches a thickness of 1.65 to 1.54 times the final plate thickness (for $^3/_4$- to 1$^1/_2$-in. plate). The slab is then held on the mill until it reaches a temperature of 1634° F (for the above-mentioned final plate thicknesses). Temperature is measured on the entry side of the four-high plate mill by means of a radiation pyrometer. The plate is moved slightly on the rolls during this and subsequent waiting intervals so that the plate will not cool nonuniformly from contact with rolls. When the plate reaches 1634° F, it is given a series of six reductions in the plate mill at the following temperatures: 1634, 1580, 1526, 1472, 1418 and 1364° F. The reductions range from 6.5 to 8.5%, and the total reduction during controlled rolling is 35 to 40%. As one example, the actual reductions used for controlled rolling of 1-in.-thick plate range from 0.08 to 0.14 in.

A number of passes are made during controlled rolling in which no reduction (or very little) is given. After each reducing pass, the plate is then taken back through the rolls (at the same pass setting) to the entry side of the mill where its temperature is recorded and where it is held until the temperature is appropriate for the next reducing pass. It was not believed that these passes involving no reduction had any effect on notch toughness behavior.

Société Anonyme Cockerill-Ougrée of Belgium is also practicing controlled rolling on about 15% of their tonnage of $^1/_2$- to 2-in. open-hearth plates, but the

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* Lightner, M. W., and Vanderbeck, R. W. "Factors Involved in Brittle Fracture." Regional Technical Meetings, AISI, 427–483 (1956).

details of the practice are somewhat different. Cockerill-Ougrée uses a powerful four-high mill for controlled rolling and believes that heavier reductions and fewer passes provide as satisfactory properties as the practice used by Royal Netherlands. Their rolling operations are carried out in the usual manner down to a thickness great enough to permit 40 to 50% reduction during controlled rolling. This reduction is accomplished in essentially three passes with reductions of about 25, 20 and 10%, respectively. A fourth pass with about 1% reduction is given mainly for flattening and thickness-control purposes. In general, their controlled rollings are divided into three groups involving slightly different rolling temperatures. In the group with the lowest rolling temperatures, controlled rolling is started at 1650° F and finishes at 1472 to 1436° F. In the group with the highest controlled-rolling temperatures, rolling starts at 1742° F and finishes at 1562 to 1517° F. Radiation pyrometers are installed on both the entry and exit sides of their plate mill, and in each pass through the mill the plate is reduced. They do not use the practice that Royal Netherlands does in which every other pass is made at the same pass setting as the previous pass. Cockerill-Ougrée claims that for plates ¾ to 1 in. thick the loss in production tonnage amounts to 10% for a finishing temperature of 1517° F and 20% for 1472° F. These losses would be greater except that Cockerill-Ougrée's controlled-rolling procedure involves processing two slabs simultaneously. A second slab is given its initial reductions while the first slab is cooling to the temperature at which controlled rolling starts.

With regard to actual benefits, limited results have been obtained by Royal Netherlands on plates rolled in the normal manner and on plates from the same heats rolled at reduced temperatures. These results indicate that low-temperature hot rolling will lower the transition temperature the following average amounts:

Type steel	No. of comparisons	C	Mn	Average decrease in transition temperature, °F: V-notch Charpy test 15 ft-lb	V-notch Charpy test 50% shear	van der Veen bend test 50% shear
Rimmed	2	0.19-0.23	0.73	38	49	78
Semikilled	5	0.13-0.18	0.58-0.77	26	37	58

It will be noted that a greater improvement is observed in the fracture-appearance transition temperature (50% shear) than in the V-notch Charpy ductility transition temperature (at 15 ft-lb). Also, the greatest improvement is obtained when transition temperature is evaluated by the van der Veen test.

A more extensive study has been done by Royal Netherlands on production material. Unfortunately, only data on controlled-rolled plate were made available, and a comparison with plates rolled in the normal manner could not be made. Their V-notch Charpy data may be compared, however, with data on plates processed in the normal manner in the United States, and this has been done in Fig. 1. Royal Netherlands plates were made by semikilled open-hearth practice. It is seen that even with controlled rolling there is a considerable effect of plate thickness on transition temperature. Making allowance for differences in composition, the controlled-rolled 0.17% C, 0.81% Mn plates have transition temperatures that are about 40 to 45° F lower than plates made to either of the ABS Class B specifications. These controlled-rolled plates seem to be on a par with the United States ABS Class C steel as judged by these V-notch Charpy data. The controlled-rolled 0.13% C, 1.12% Mn plates have 25° F lower transition temperatures than the 0.16% C, 1.25% Mn plates produced in the United States by the usual rolling methods.

Data obtained by Cockerill-Ougrée on production material are also shown in Fig. 1. Their semikilled, controlled-rolled, 0.14% C, 0.85% Mn plates are quite similar in notch toughness behavior to the controlled-rolled 0.17% C, 0.81% Mn Royal Netherlands plates. The small difference in transition temperature can be accounted for by the slight differences in composition. A

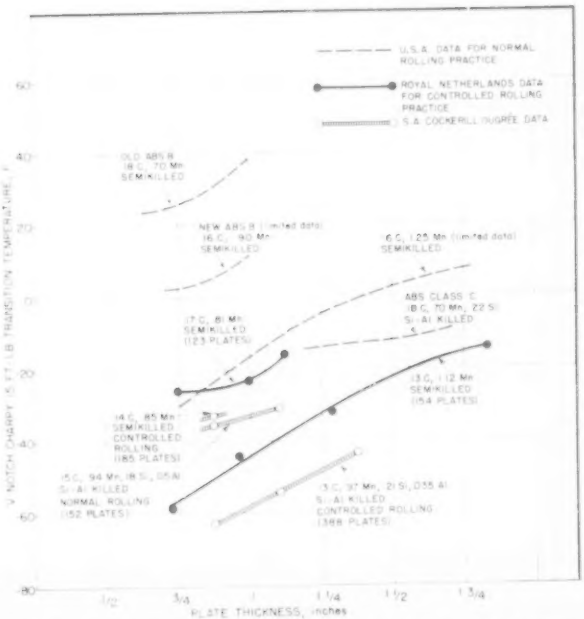
U.S.A. DATA FOR NORMAL ROLLING PRACTICE
ROYAL NETHERLANDS DATA FOR CONTROLLED ROLLING PRACTICE
U.S.A. COCKERILL (OUGRÉE DATA
OLD ABS B (.18 C, .70 Mn SEMIKILLED
NEW ABS B (limited data) (.16 C, .90 Mn SEMIKILLED
(.17 C, .81 Mn SEMIKILLED (123 PLATES)
ABS CLASS C (.18 C, .70 Mn, .22 Si Si-Al KILLED
(.13 C, 1.12 Mn SEMIKILLED (154 PLATES)
(.14 C, .85 Mn SEMIKILLED CONTROLLED ROLLING (185 PLATES)
(.15 C, .94 Mn, .18 Si, .055 Al Si-Al KILLED NORMAL ROLLING (152 PLATES)
(.13 C, .97 Mn, .21 Si, .035 Al Si-Al KILLED CONTROLLED ROLLING (388 PLATES)
V-NOTCH CHARPY, 15 FT-LB TRANSITION TEMPERATURE, F
PLATE THICKNESS, inches

Fig. 1 Effect of controlled low-temperature hot-rolling practice on the notch toughness of plate product

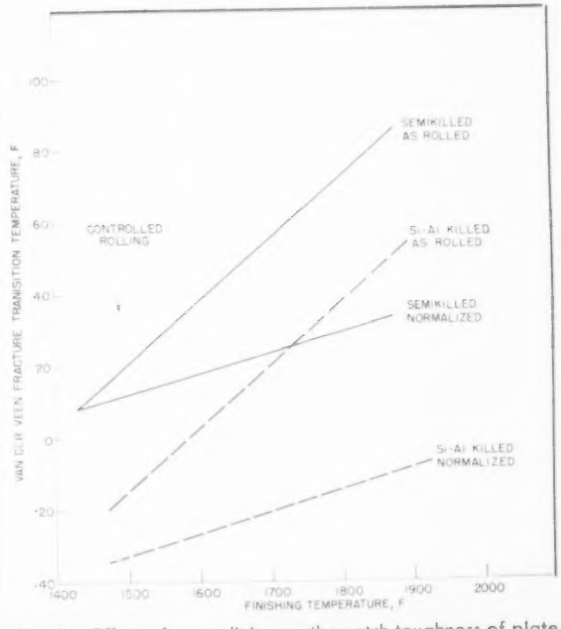

Fig. 2 Effect of normalizing on the notch toughness of plate rolled at various temperatures

direct comparison may be made for Si-Al-killed plates produced at Cockerill-Ougrée since they developed information on both controlled and normal rolling. It is seen that controlled rolling lowers the transition temperature of this type of steel 25° F on the average. Since the composition of the controlled steel is slightly more favorable (0.13% C, 0.97% Mn as opposed to 0.15% C, 0.94% Mn), it seems likely that an improvement of about 20° F would be expected with equivalent compositions.

Judging from all of these data, an average improvement in the 15 ft-lb V-notch Charpy transition temperature of 20 to 45° F seems to be possible by the use of low-temperature hot rolling. The data also seem to indicate that the amount of improvement decreases as the quality of the steel increases. Thus, the semikilled Class B type of steel shows the biggest improvement, whereas the Si-Al-killed steel appears to show the least improvement. All or most of this improvement in notch toughness seems to be associated with a refinement of the ferrite grain size.

The general response of hot-rolled carbon steel to normalizing was shown by Dr. van der Veen to take place in accordance with Fig. 2. It is to be noted that this representation of behavior is based upon the van der Veen notch-bend test. Normalizing did not improve the toughness of controlled-rolled semikilled plates, but it did for controlled-rolled Si-Al-killed product (this is especially true for thick plate) because of a further refinement in grain size resulting from normalizing.

Scottish and Swedish Hot-Rolling Practices

Colvilles Ltd. of Scotland have conducted some controlled-rolling studies within the limitations imposed by production conditions. These studies were discussed with Mr. William Barr, director of Colvilles Ltd., and it was determined that, within the possible range of control which could be imposed in Colvilles' works, the low-temperature rolling lowered the van der Veen transition temperature and the Charpy V-notch 50% shear transition temperature appreciably. The V-notch Charpy 15 foot-pound transition temperature, however, was lowered only slightly. The small effect on the 15 ft-lb temperature probably resulted because the change in finishing temperature was not very marked. For plates from 0.9 to 1.3 in. in thickness, the average controlled-rolled finishing temperatures were in the range of 1580 to 1780° F compared with finishing temperatures of 1670 to 1970° F for the uncontrolled plates. Thus, the average drop in finishing temperature was about 90° F, which is not as much as was obtained at the Royal Netherlands Steelworks or at the Cockerill-Ougrée Works. The controlled-rolling procedure adopted was to subject the plates to six passes through the mill without any reduction when they were approximately 1½ times their final thickness. Under the conditions prevailing at this particular mill, this procedure did not appreciably reduce mill output, but any further lowering of the finishing temperatures would have had an adverse effect in this direction. Colvilles therefore came to the conclusion that it was more economical to refine the grain and lower the transition temperature by subsequent normalizing of the plates.

Domnarfvets Jernverk in Domnarvet, Sweden, was among the first to investigate the possibilities of controlled rolling, the early investigations being carried out as far back as 1940. All of their semikilled plates are presently rolled to a certain degree by this process with the objective of obtaining a reduction of at least 20% at a temperature below 1650° F. In rolling steels at this temperature, a twofold effect is said to take place, one involving a decrease in grain size and the other an accentuation of the ferrite-pearlite banding. It is claimed that the steel is worked within the transformation range where two microstructural constituents are present, austenite and ferrite. Working the steel within this range crushes the newly formed ferrite grains and at the same time helps to create a conspicuous ferrite-pearlite banding. Banding is claimed to be the explanation for the fact that the improvement in notch toughness is greater when measured by a fracture transition temperature than by a ductility transition temperature. The effect of normalizing is believed to depend mainly on the inherent grain size. Thus, the good notch toughness that may be obtained in rimming steel by controlled rolling may be destroyed by normalizing, whereas the notch toughness of killed steel made by fine-grain practice is always improved by normalizing. Controlled-rolled semikilled steels are said to respond usually in a favorable way to the normalizing treatment. The plate steels of this mill are all made by electric-furnace practice and are rolled directly from the ingot, without an intermediate slabbing operation.

Acknowledgment

The above report was made possible through the cooperation and helpfulness of a number of people in Europe, and their willingness to provide this information is very much appreciated. In addition to Dr. van der Veen and Mr. Barr who are mentioned in the text, the writer is indebted to H. Herbiet, assistant to the vice-president, Applied Research, S. A. Cockerill-Ougrée and to P. Matton-Sjoberg, chief metallurgist, Domnarfvets Jernverk, for supplying data pertaining to practices and investigations at their plants.

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INERT-GAS-SHIELDED CONSUMABLE-ELECTRODE WELDING OF MOLYBDENUM

Studies of arc stability and metal transfer in molybdenum arcs, and the immediate problems in adapting the inert-gas-shielded consumable-electrode process for molybdenum welding, are discussed in this paper

BY N. E. WEARE, R. E. MONROE AND D. C. MARTIN

ABSTRACT. As part of an over-all program to improve the ductility of molybdenum weldments, studies were initiated to adapt the inert-gas-shielded consumable-electrode arc-welding process to molybdenum. This paper covers the work required to improve metal transfer and arc stability in molybdenum arcs before starting complete evaluation of this welding process.

Arc stability and metal transfer could be improved to the greatest extent by using d-c, straight polarity, an electrode wire coated with a compound to increase the emission of electrons, and a helium shield. These same conditions also produced the best weld-bead contour, and lessened the amount of weld-metal cracking due to shrinkage stresses developed in the weldment. Porosity was not evident when using either a leading-trailing shield or a dragging shield, and when welding on arc-cast molybdenum.

Metallographic and bend-test comparisons were made between these welds and tungsten-arc welds in ½-in. thick molybdenum. The weld-metal grain size was about the same for both weldments. Room-temperature bend-test ductility was very low for both weldments. The results of this comparison indicated that the inert-gas-shielded consumable-electrode welding process may have its best application in welding thick molybdenum plate, whereas tungsten-arc welding would be better for welding sheet ¼ in. thick or less.

Introduction

Methods of improving the low-temperature ductility of molybdenum weldments have been under investigation for several years. One phase of this investigation was devoted to adapting the inert-gas-shielded consumable-electrode welding process to molybdenum. Studies of arc stability and metal transfer in molybdenum arcs, which were immediate problems in adapting the consumable-electrode process for molybdenum welding, are discussed in this paper. The results of some preliminary tests of the properties of joints made with the consumable-electrode process are reported.

One of the major deterrents to the use of molybdenum in high-temperature reactors is the low room-temperature ductility of molybdenum weldments. In recent years, important advances have been made in improving weldment room-temperature ductility. One investigation[1] made to compare tungsten-arc welds in a large number of alloys indicated that: (1) weldments in carbon-deoxidized molybdenum were as ductile as weldments in experimental high-purity titanium-neutralized molybdenum, and (2) weldment room-temperature bend ductility was improved by grinding the weld surface. Another study[2] was made to ascertain the effects of variables on the ductility of tungsten-arc welds in molybdenum and to determine if welds of consistent ductility could be made in different heats of arc-cast molybdenum of about the same carbon content.

The bend-test results for welds made in the latter study indicate that there is a limit to tungsten-arc weldment ductility, owing to the large weld-metal grain size. The maximum average permanent bend angle at room temperature for welds made in a high-purity dry-box atmosphere was about 65°, as determined by a fast bend test. Tungsten-arc welds made outside the dry box, using inert-gas shielding, were not as ductile as those in the dry box. It was thought that the inert-gas-shielded consumable-electrode process would produce weldments with a finer weld-metal grain size and a narrower heat-affected zone, due to a more rapid energy input. A smaller weld-metal grain size would increase ductility and would increase the tolerances for impurities if the molybdenum were welded outside a dry box. All weldments made during the course of this investigation were made in air with an inert-gas shield, using direct current.

The use of a consumable electrode introduced variables which were not present with the tungsten-arc welding process. The fact that the electrode was being consumed and metal was being transferred through the arc gave rise to problems of metal transfer and arc stability. The results of studies reported here indicate that arc stability and metal transfer can be improved by: (1) using high current densities, (2) using helium rather than argon for shielding, and (3) coating the arc cathode with a compound to improve the emission of electrons. Other studies were made of d-c polarity and shielding devices.

When good arc conditions were established, slight variations in parameter, principally in weld speed, were made to obtain an acceptable weld-bead contour. It was found that the best weld-bead contour could be obtained by welding in helium, with d-c, straight polarity (electrode negative), and with an emissive coating on the electrode.

Weld cracking and porosity were minor problems which were virtually eliminated once good welding conditions were established. Preliminary tests with butt joints indicated further studies of joint design are necessary. An inconclusive comparison was made between a tungsten-arc weld and a consumable-electrode weld in ½-in. thick molybdenum sheet. There appeared to be very little difference in weldment macrostructure or ductility for weldments in ½-in. thick sheet.

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Materials

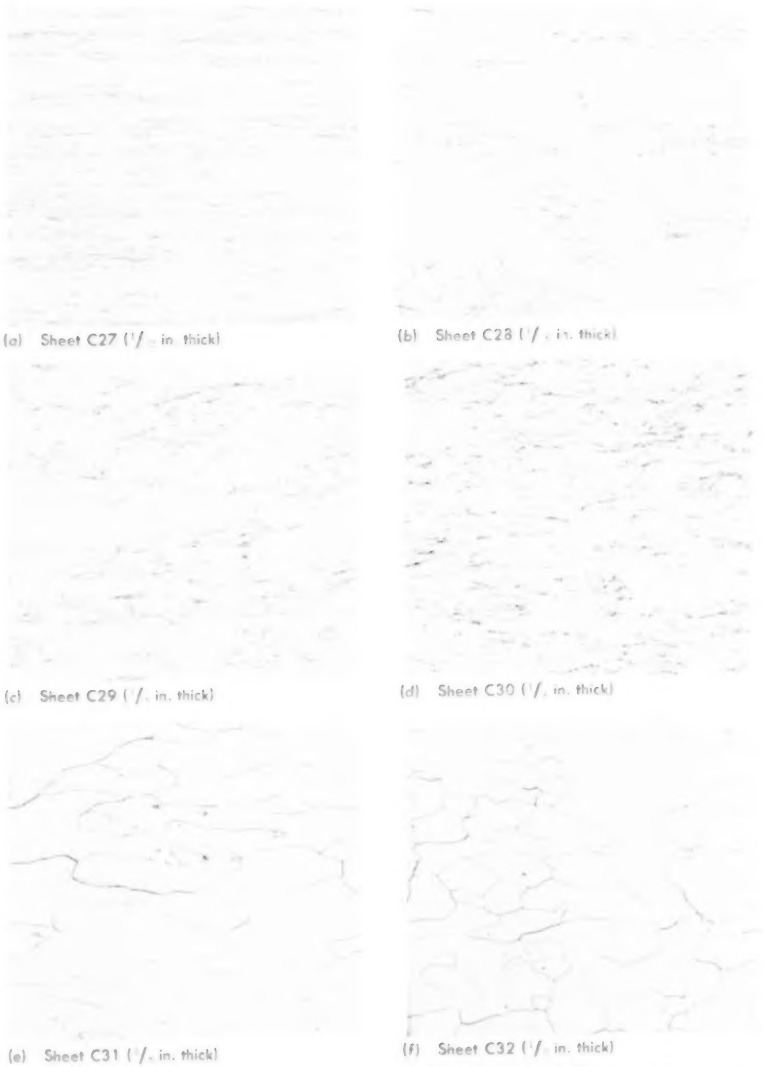
Arc-cast carbon-deoxidized molybdenum sheet ($^1/_{32}$ through $^1/_4$ in. thick) and electrode wire (0.020, 0.040 and 0.062 in. diam) were used for this study. Metallographic examinations of the sheet were made. The photomicrographs in Fig. 1 show that none of the sheet was in what could be considered the fibered condition. The $^3/_8$- and $^1/_4$-in. thick plate had more elongated grains near the surface. The chilling effect of the rolls cooled the plate surface enough to allow more cold work to be put into the surface layer. Vickers hardness readings were taken for all the sheet and indicated that very little cold reduction occurred in the interior of the $^3/_8$- and $^1/_4$-in. thick plate. The available data for the molybdenum sheet are given in Table 1. Fabrication data were not available for the sheet or wire.

Previous experience with $^1/_{16}$-in. thick molybdenum sheet with a coarse elongated grain structure has shown this type of grain structure to be much less ductile at room temperature than a fibered grain structure.[2] Room-temperature bend tests were made on Sheet C29 only, and the bend ductility after stress relief (1800° F, 1 hr, in helium) was found to be poor. The average permanent bend angle after fracture was 24-deg. This does not compare favorably with the 75-deg average bend angle for $^1/_8$-in. thick sheet (C3) used in a previous study.[1]

Three electrode wire sizes were available for this study: 0.020, 0.040 and 0.062 in. diam. Most of the work was conducted with the 0.040-in. diam wire. The carbon content of all wire was 0.022%.

Experimental Procedures

The consumable-electrode welding process involves more variables than the tungsten-arc process previously used for molybdenum. In the process, the tip of the electrode is melted and metal is transferred through the arc as a spray of fine particles. Additional variables introduced by the use of a consumable electrode are: (1) arc stability, (2) metal transfer, and (3) electrode-burn-off rate. These variables are all interrelated to some extent. This section describes the equipment, cleaning method, welding procedures and methods used to evaluate welds.



(a) Sheet C27 ($^1/_{32}$ in. thick)

(b) Sheet C28 ($^1/_{16}$ in. thick)

(c) Sheet C29 ($^1/_8$ in. thick)

(d) Sheet C30 ($^1/_4$ in. thick)

(e) Sheet C31 ($^3/_8$ in. thick)

(f) Sheet C32 ($^1/_4$ in. thick)

Fig. 1 Typical interior microstructure of molybdenum sheet for welding study. Longitudinal sections. Murakami's etch. X100

Table 1—Summary of Available Data on Molybdenum Sheet for Welding Studies

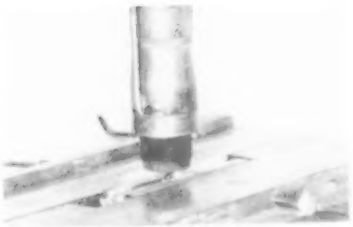
Sheet	Thickness, in.	Carbon content, %	Microstructure	DPH (10-kg load)	Average bend angle at 25° C*
C27	$^1/_{32}$	0.019	Elongated fine grains	274	
C28	$^1/_{16}$	0.019	Elongated coarse grains	284	
C29	$^1/_8$	0.011	Elongated coarse grains	257	24
C30	$^1/_4$	0.019	Elongated coarse grains	251	
C31	$^3/_8$	0.019	Elongated very coarse grains†	210	
C32	$^1/_4$	0.019	Nearly equiaxed coarse grains†	189	

* After stress relief at 1800° F for 1 hr in flowing helium.
† The grains were more elongated near the sheet surface.

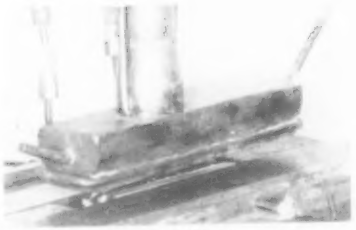
Equipment

The equipment used for this study consisted of a 900-amp d-c welding generator which maintained a constant arc voltage, a welding head which provided a constant electrode-feed rate, and a moving carriage. The current was regulated by the welding generator to that required to maintain a given electrode burn-off rate. A constant-electrode-feed-rate welding head was used for this study, since it provided good control of welding variables. Current and arc voltage were measured by recording meters.

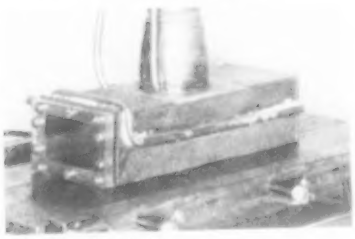
Three types of gas shields were used in this study. These were: (1) a standard shielding cup, (2) a leading-trailing shield, and (3) a dragging shield. The standard shielding cup (Fig. 2*a*) was a water-cooled cup with a 1-in.



(a) Standard 1-in.-ID shielding cup



(b) Leading-trailing shield unit



(c) Dragging shield

Fig. 2 Shielding devices for the inert-gas-shielded consumable-electrode welding of molybdenum

diam gas orifice. Protection was provided for the molten weld pool and the filler wire. To improve the shielding, a water-cooled leading-trailing shield unit was built (Fig. 2b). The leading portion of the shield protected the unwelded molybdenum ahead of the arc while the trailing portion protected the completed weld. This unit was made to fit the shielding cup. A gas baffle consisting of several layers of fine-mesh copper screen was brazed into the bottom of the shield. This gas baffle distributed the gas flow evenly. Gas was admitted from the leading and trailing ends of the shield.

To improve the shielding further, a dragging shield (Fig. 2c) was constructed which could slide in direct contact with the molybdenum being welded. When this shield was purged with helium, it acted as a small inert-gas welding chamber. This shield functioned much the same as the dragging shield used in a previous study,[2] which was used for making tungsten-arc welds for comparison with consumable-electrode welds.

To conserve material, a jig was made to hold 1- by 4-in. specimens of $\frac{1}{8}$- through $\frac{1}{2}$-in. thick plate. A copper backing bar was recessed so that a $\frac{1}{16}$-in. molybdenum backing strip could be used to prevent copper pickup when penetration was complete. The weld specimens were held in a "picture frame" by copper plates on either side, of the same thickness as the molybdenum being welded. Molybdenum starting and run-off tabs backed by copper bars completed the picture frame. This jig provided a flat surface on which the dragging shield could slide. This jig is shown partially in Fig. 2.

Cleaning Methods

Welding conditions were evaluated by making a series of bead-on-plate welds on single plates of molybdenum. In this study, only test joints were cleaned in the chromic-acid etch normally used for cleaning molybdenum before welding. To save time and trouble, the molybdenum sheet was cleaned between welds simply by abrading it with emery paper. Previous investigations had shown that welds made on sheet which had been abraded had nearly as good ductility as welds on sheet cleaned in chromic acid.

The wire had a black-oxide coating on its surface when it was received from the fabricator. This heavy oxide was removed by etching in the chromic-acid solution.[2] The wire was then wound on a spool and placed on the welding head. Slight oxide films formed on the wire were then removed by running out a length of wire and polishing it with emery paper. The wire was then rewound on the spool and used for welding.

Welding Procedures

To insure adequate shielding with the leading-trailing and dragging shields, the shields were purged with inert gas for about 30 sec prior to welding. When the weld-start switch was closed, a time delay allowed about 5 sec for the purging of the shielding cup. At the end of this time delay, controls simultaneously initiated the electrode-wire feed and the specimen carriage, and completed the power circuit for the arc. The wire contacted the molybdenum plate and struck the arc. During the welding operations, the electrode feed (burn-off rate) was constant, and the welding generator maintained a constant preset arc voltage. The current output of the generator was the amount required to maintain a constant arc voltage, regardless of the burn-off rate. In order to determine the effect of single variables, all the other welding conditions were held nearly constant. However, when changing d-c polarity or type of shielding gas, it was necessary to change other conditions to compensate for the differences in arc and metal-transfer characteristics.

As will be discussed in a later section, the arc was very unstable when welding on oxide-free sheet (reverse polarity) or when welding with oxide-free wire (straight polarity). The arc stability could be improved by coating the cathode (negative electrode) with a compound which increased the emission of electrons. For reverse polarity, the plate being welded was first cleaned and then a dilute solution of cesium chloride in distilled water was painted on the joint and allowed to dry, leaving a thin film of the chloride. When straight polarity was used, the clean electrode wire was coated with the chloride.

If the arc appeared steady, adjustments were then made in the weld speed to produce a good weld-bead contour with no irregularities. When welding conditions were established which appeared to be good, single-vee joints, square-butt joints, or bead-on-plate welds were made to evaluate these conditions further.

Several butt joints were prepared and welded using conditions chosen from the bead-on-plate welds. Single-vee joints with 15-, 20-, 30- and 45-deg bevels were prepared from $\frac{1}{8}$-in. plate, and 20-deg bevels were used on $\frac{3}{8}$- and $\frac{1}{2}$-in. thick plate. Square-butt joints were also made in $\frac{1}{8}$-in. plate. All joints were made using 0.040-in. diam electrode wire. Some bead-on-plate welds were made using 0.062-in. diam electrode wire. No welds were made with 0.020-in. diam electrode wire, since the welding equipment required modification to facilitate its use with this small-diameter wire.

Butt joints were prepared from two pieces of plate $\frac{1}{2}$ in. wide by 4 in. long. The bevel was ground and the halves were tacked together by tungsten-arc welding in a dry box. The joints were then placed in the picture-frame jig described in a previous section. A $\frac{1}{16}$-in. thick molybdenum backing strip was used for all joints to prevent pickup of copper during welding.

Evaluation of Welding Conditions

During the course of this investigation, numerous bead-on-plate welds required rapid evaluation to determine good welding conditions for the inert-gas-shielded consumable-electrode welding of molybdenum. Welding conditions were evaluated by visual examination of the arc and the completed weld.

The arc was observed to determine arc stability. An unstable arc would sputter, wander, or vary in length. When the arc was unstable, the voltage

and current traces were very irregular. Conversely, a stable arc was steady and had smooth arc-voltage and current traces.

The weld bead was examined for weld-bead contour and, occasionally, for penetration. If a weld bead had a good contour and sufficient penetration, and the arc was stable, the welding conditions were considered good. Poor weld-bead contours indicated that a change in some variable was necessary.

Radiographic examinations were not made on weldments to determine the extent of porosity and cracking. Porosity was sometimes visible on the surface of the welds. Metallographic examinations were used to supplement other observations on the best welds produced.

Bend tests were made at room temperature on $\frac{1}{8}$-in. thick sheet and weldments. The specimens were ground flat and the tension face was rough polished, since it had previously been shown that this improved weldment ductility. The sheet and weldments were bent to fracture, and the permanent bend angle after fracture was measured. The testing conditions are listed below:

Type of test	Simple single-point-loaded bend test
Testing temperature	25° C
Deflection rate	1 ipm
Strain rate	0.032 in. per in. per sec at start of bend
Specimen dimension	$\frac{1}{8}$ by $\frac{3}{4}$ by approximately 1 in.

This test is described in detail in a previous paper.[1]

Experimental Results

Initial welding tests defined the problems which required solution before the inert-gas-shielded consumable-electrode process could be used for welding molybdenum. The major difficulties were associated with arc stability and metal transfer through the arc. Minor problems involved: (1) weld-bead contour, (2) weld cracking, and (3) porosity. It was thought that these minor problems might be solved once good welding conditions were established. Results of this investigation have indicated that this was true.

Arc Stability and Metal Transfer

A stable arc is one which does not wander, remains constant in length, and is not extinguished frequently as a result of short circuits caused by large drops of molten metal. Arc stability and metal transfer are interrelated. If metal transfer is of a drop type rather than the preferred spray type, large drops can short-circuit the arc and cause sputtering. If the arc is not stable, metal transfer will be inconsistent. An unstable arc can also cause turbulence in the inert-gas shield and draw air into the shield. Good metal transfer is of the spray type, occurring in the inner cone of the arc, with no spatter.

Table 2—Effects of Variables on Arc Stability and Metal Transfer

0.040-In. Diam Electrode, Helium Shielding Unless Noted Otherwise

*Variable**	*Variation*	*Effect of variation*
Electrode current density (dc, reverse polarity)	160,000 to 365,000 amp per sq. in.	Are more stable at higher currents
Electrode current density (dc, straight polarity)	285,000 to 415,000 amp per sq. in.	Are slightly more stable at higher currents; are "buried" beneath plate surface at highest currents studied
D-C polarity	Reverse polarity (electrode positive) to straight polarity (electrode negative)	More spatter with straight polarity, neither condition produced stable arc; straight-polarity arc more easily stabilized with emissive coatings
Shielding gas	Argon to helium	Better arc stability in helium
Shielding devices	Cup, leading-trailing shield, and dragging shield	Very little effect; less spatter with improved shielding
Wire surface (d-c, straight polarity)	Clean to emissive coating (CsCl)	Erratic arc with clean surface; emissive coating stabilized the arc and allowed lower burn-off rates to be used at the same current
Sheet surface (d-c, reverse polarity)	Clean, slightly oxidized surface, emissive coating (CsCl)	Erratic arc with clean surface; stable arc with either emissive coating or oxidized surface

* All other variables were held nearly constant when possible.

Initial welding studies were made using reverse polarity (electrode positive) on molybdenum sheet which had an oxidized surface. Conditions were established which appeared to be acceptable for welding molybdenum on oxidized sheets. However, when these welding conditions were used on molybdenum sheet from which the surface oxide had been removed, a very unstable arc resulted. Apparently the arc had been stabilized by the presence of molybdenum oxide on the sheet surface. The arc stability may have been aided by the molybdenum-oxide film on the surface, molybdenum-oxide vapor in the arc, or by the presence of oxygen in the inert-gas shield. It has been shown in other investigations that it is difficult to obtain a stabilized arc on clean metal surfaces.[3] Oxygen additions are made to argon to aid arc stability for welding steels, and several investigations have shown that oxide films on the negative electrode aid in stabilizing the arc by increasing the emission of electrons. Since oxygen is highly detrimental to the ductility of molybdenum weldments, other methods were sought to stabilize the arc for welding on cleaned sheet.

Several variables were studied to determine their effects on arc stability and metal transfer. These were: (1) current density, (2) d-c polarity, (3) shielding gas, (4) shielding, and (5) emissive coatings. The effects of these variables are summarized briefly in Table 2.

Current Density

It is well known that current density plays a very important role in determining the type of metal transfer. At low current densities the metal transfer is of a large-drop type. In this type of metal transfer, the tip of the electrode melts until a drop forms which is large enough to be separated from the electrode by gravity. Above a certain current value, the metal transfer becomes the spray type. Minute drops of metal are separated from the electrode and propelled at high velocities as a fine spray by electromagnetic forces. It was found that when using reverse polarity in helium, a more stable arc resulted at higher currents. Exact current values for the transition from drop-type to spray-type metal transfer were not determined. Continued presence of spatter indicated that optimum conditions were not reached. Current densities of 300,000 to 400,000 amp per sq. in. were used with 0.040-in. diam molybdenum electrodes and about 250,000 amp per sq. in. were used with the 0.062-in. diam electrodes. This is considerably more than the 100,000 to 150,000 amp per sq. in. used with a 0.062-in. diam steel electrode in the normal welding range. In this study, current did not appear to have a great effect on arc stability and metal transfer for straight-polarity welding.

Direct-Current Polarity

A study was also made to determine the best d-c polarity for welding molybdenum. Normally, for the weld-

ing of steel by the inert-gas-shielded consumable-electrode process, reverse polarity (electrode positive) produces the spray-type metal transfer mentioned above. On the other hand, straight-polarity (electrode negative) welding with an uncoated steel electrode produces large drops of molten metal at the tip of the electrode. Arc stability and metal transfer can be improved for straight-polarity welding by coating the electrode with a thin film of an emissive compound, as will be discussed later in this paper.

Initial welding studies using the inert-gas-shielded consumable-electrode process were made with reverse polarity in helium. The arc was stable when the molybdenum sheet had an oxidized surface, but a stable arc could not be maintained on a clean surface. On a clean molybdenum surface the arc wandered considerably and was very unstable. Changing the polarity did not improve arc stability. With straight polarity in helium the arc length was constantly changing, while with straight polarity in argon the cathode spot could be seen moving up and down the electrode wire. The arc was not stable using either polarity without coating the cathode with a compound to increase electron emission. Even with the coating, the straight-polarity arc was not completely stabilized in argon. However, the weld beads produced with this polarity had better contour and penetration and were not as irregular in shape as reverse-polarity weld beads. When welding steel, much higher burn-off rates are realized when straight polarity is used. This effect was not observed with molybdenum.

Shielding Gas

Previous welding studies using the tungsten-arc process indicated that helium was more suited for welding molybdenum than argon.[3] Welds made in helium had a better contour and deeper penetration than welds made in argon. Using argon and straight polarity, cathode instability was manifested by wandering of the cathode flame above the tip of the electrode. This phenomenon is not unusual when welding in pure argon.[4] Using helium and straight polarity, the cathode spot was stable on the end of the electrode, but the arc length was constantly changing. Emissive compounds on the electrode stabilized the arc length in helium but did not completely eliminate cathode instability in argon. These observations indicate that helium gives better arc stability than argon. Argon-helium or argon-hydrogen mixtures might give better arc stability than pure argon. Argon-hydrogen mixtures have been used for tungsten-arc welding to approach the heat developed using helium.[5]

Shielding

Three shielding devices were used for this study: (1) a standard shielding cup, (2) a leading-trailing shield, and (3) a dragging shield. The shielding cup was found to be inadequate for shielding molybdenum because it did not prevent severe oxidation of the unwelded sheet ahead of the arc. Considerable spatter emanated from the weld area, causing some interruption of the inert-gas shield.

The leading-trailing shield provided better protection than the shielding cup. However, the shield could not be brought close enough to the weld to insure good protection. Spatter was lessened to some degree by the use of the leading-trailing shield, but was still enough to cause some shield interruption.

The dragging shield appeared to improve the inert-gas-shielding further. Some spatter was still evident, but it was confined within the shield and did not cause shield interruption.

In this study, no attempt was made to determine the effect of shielding on arc stability or metal transfer. The lowering of the amount of spatter achieved by improving the shielding indicates some degree of improvement in arc stability and metal transfer. No study was made of the effect of shielding or inert-gas flow rates on weldment ductility.

Emissive Coatings

The results of molybdenum welding tests using the inert-gas-shielded consumable-electrode process with straight polarity and a clean molybdenum electrode indicated that a method was required to improve the arc stability and metal-transfer characteristics using unoxidized materials. As a result of the better understanding of arc phenomena acquired in recent years, many advances have been made in the inert-gas-shielded consumable-electrode welding process. One of the most significant of these advances is the use of coatings to increase the emission of electrons and thus aid arc stability and improve the metal-transfer characteristics of straight-polarity welding arcs. Improvement in arc stability for straight-polarity welding of molybdenum was very important, since this polarity provided better appearing welds with deeper penetration and less cracking than did reverse polarity.

For many years, it has been known that the thermionic emission in electron tubes could be improved by surface coatings which lowered the thermionic work function of the cathode. The work function is a quantity related to the energy required to make an electron leave a surface; the smaller the work function, the lower the temperature at which a given electron emission

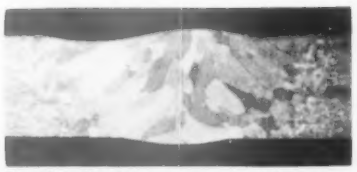


Fig. 3 Photomacrograph of tungsten-arc weld C29-8

Murakami's etch, $\frac{1}{16}$-in. sheet. X10. (Reduced by $\frac{1}{3}$ upon reproduction)

Fig. 4 Photomacrograph of inert-gas-shielded consumable-electrode weld C29-6

Murakami's etch, $\frac{1}{16}$-in. sheet; $\frac{1}{16}$-in. backing strip. X10. (Reduced by $\frac{1}{3}$ upon reproduction)

Fig. 5 Microstructure of weld C29-6 showing carbides precipitated in the grains and along the grain boundaries

Murakami's etch. X250. (Reduced by $\frac{1}{3}$ upon reproduction)

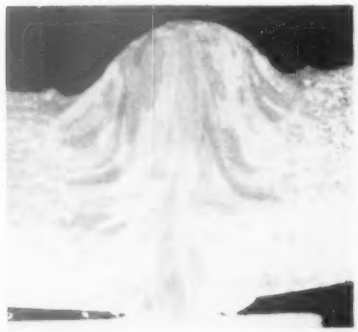


Fig. 6 Macrostructure of a two-pass consumable-electrode weld in $\frac{1}{4}$-in. thick molybdenum plate (weld C30-5)

X 10. (Reduced by $\frac{1}{3}$ upon reproduction)

can be attained. In the straight-polarity welding arc, it is impossible for a clean wire to support the arc by thermionic emission of electrons, since its area of emission is restricted and its work function is high. By coating the surface with a compound which lowers its thermionic work function, the mode of metal transfer with straight polarity is improved, metal drop size and spatter are reduced, and material movement becomes more axial. The arc then becomes stable, and has the same geometry as a reverse-polarity arc. Activated electrodes are now coming into use for straight-polarity welding of the more common metals.[6,7]

To lower the thermionic work function, a metal or metallic compound with an ionization potential less than that of the electrode material must be used for the coating. Metals or compounds of metals falling in the alkali, alkaline-earth, or rare-earth families are the best coating materials.[7] Oxides of metals generally have better emission characteristics than the pure metals. Only minute amounts of these compounds are required to activate the electrode. When argon-oxygen mixtures are used for welding steel, arc stability and metal transfer are improved. Iron oxide is formed on the electrode and increases the flow of electrons. Molybdenum oxide on the molybdenum cathode (negative electrode) may aid arc stability in much the same manner. This would account for the decreased arc stability when the oxide was removed by etching.

In the limited work done during this investigation, only cesium chloride coatings were used. Some of the initial work was done with the emissive compounds using reverse polarity. In this case, the sheet was coated with the compound. Arc stability was increased. The effect of the emissive compounds was more striking when the coated electrode was used for straight-polarity welding.

When the coated electrode was used for straight-polarity welding of molybdenum, the burn-off rate at a given current could be lowered below that required for an uncoated electrode. This means that, at a given burn-off rate, a coated electrode will produce higher currents and deeper penetration than an uncoated electrode. This is illustrated in Table 3.

In helium, the arc length was constantly changing when an uncoated electrode was used. Coating the electrode with cesium chloride stabilized the arc length. In argon, the arc was not completely stabilized by coating the electrode. The cathode spot still wandered up and down the electrode. Considerable spatter was still very evident with straight polarity in helium or argon. Further work should be carried out using coated electrodes to improve arc stability and metal transfer and to study the effect of other variables on arc stability and metal transfer when coated electrodes are used.

Table 3—Effect of Emissive Coatings on Burn-off Rate and Current for Straight-Polarity Helium-Shielded Welding of Molybdenum

Coating	*Current, amp*	*Burn-off rate, ipm*
None	400	400
CsCl	460	400
CsCl	400	325

Spatter

Spatter is simply the expulsion of drops of molten metal from the arc or weld area. Though spatter was much more noticeable when straight polarity was employed, it occurred with reverse polarity also. With straight polarity, metal is generally transferred through the arc as large drops. The erratic motion of these drops causes the arc plasma to shift, resulting in an acceleration of drops away from the weld in the form of spatter. Spatter may also be caused by mechanical agitation and explosion of large drops which touch the plate before being separated from the wire, causing short circuits.[8] In reverse-polarity welding of molybdenum, spatter could have been caused by poor metal transfer.

No attempt was made to determine the cause of the spatter encountered. It was noted that the amount of spatter was lessened by improved shielding and by coating the wire with emissive compounds. Spatter is undesirable because it wastes filler metal and can cause interruption of the inert-gas shield.

Weld-Bead Contour and Penetration

Even though a stable arc was maintained with good metal transfer, the shape and contour of the weld bead had to be consistently acceptable. Penetration is very important in molybdenum welding, especially for the first pass of multipass joints, where complete penetration at the base of the joint is required. An ideal weld would have a low and nearly flat contour on the top surface. With pure metals or alloys having narrow freezing ranges, it is not possible to obtain such a contour because of the rapid freezing. In this study, weld-bead contour was usually regulated by changing the weld speed at conditions which produced a stable arc.

Weld beads made using reverse polarity were narrow and had a very high contour. Penetration was not very deep with reverse polarity. In one single-vee butt joint, the arc was slightly off center. This resulted in incomplete penetration at the joint base, and imperfect fusion between the weld bead and one side of the joint.

Straight polarity produced a weld bead with a wider and lower contour, very similar to straight-polarity beads in steel. In addition, much more heat was put into the plate when straight polarity was used, resulting in a marked increase in penetration. A single-vee butt joint was made with the arc to one side of the joint line, using straight polarity. Penetration was not complete, but unlike the similar weld made with reverse polarity, the weld bead was fused on both sides of the joint.

The weld beads described above were made in helium. Weld beads made in argon had less penetration and generally had a higher bead contour. As was suggested in a previous section, perhaps a mixture of argon and hydrogen could be used to duplicate the results found for helium.

The best weld-bead contour was produced by welding with straight polarity in helium using an emissive coating on the electrode at a relatively low burn-off rate (325 ipm with 0.040-in. diam wire). A high weld bead is due to the rapid freezing of the molybdenum, which does not allow time for the molybdenum to flow. The best weld-bead contour was made at conditions which supplied the most heat into the weld, perhaps allowing a slightly longer time for molten filler metal to flow.

Cracking

Many of the butt joints made during the early portion of this investigation were badly cracked. These cracks were usually transverse to the weld and ran through some defect in the weld which caused a stress concentration or a reduced cross section. Basically, the difficulty stemmed from longitudinal stresses in the weld due to shrinkage. Cracking was a particularly serious problem when the butt joints were made using reverse polarity.

When polarity was changed to straight polarity, cracking was less evident. Since more heat was put into the molybdenum plate being welded when straight polarity was employed, the additional heat may have alleviated shrinkage stresses by acting as a preheat-postheat cycle, thus reducing the tendency for cracking. Further reduction in cracking might be realized by an additional preheat-postheat cycle.

In multipass single-vee butt joints, the first weld pass could be made without any cracks. Additional weld passes caused transverse cracks to develop in the first pass. These cracks then ran into the subsequent passes as the shrinkage stress was built up.

Longitudinal weld cracks appeared in a few multipass single-vee butt joints.

Shrinkage of the weld metal in a direction transverse to the weld direction caused distortion, placing the root of the first weld pass in tension. If penetration by the first pass was not complete, a notch was present at the joint line. Then, when subsequent passes were made, longitudinal cracks could easily initiate at the notch and propagate in the first weld pass. Cracking due to shrinkage stresses might be eliminated by using a minimum amount of filler metal, or by making welds in a single pass.

It was mentioned previously that fractures occurred through some inconsistency in the weld bead where a reduced cross-sectional area or a stress concentration existed. Cracking tendencies of molybdenum weldments would be lessened to a large degree if weld beads could be made with a consistent cross section. Complete penetration of the first weld pass would eliminate longitudinal cracking due to the presence of a notch at the joint line.

Porosity

Porosity was not a major problem with the inert-gas-shielded consumable-electrode welding of arc-cast molybdenum. The majority of welds were very sound, as shown in Figs. 4 to 6 which appear later. Porosity was noted in some bead-on-plate welds when the arc was unstable, metal transfer was poor, or shielding was inadequate. When welding conditions were good, very little porosity was noted, except at the starting end of the weld before the arc became stabilized.

Butt Joints

Welding conditions were evaluated during the investigation by making bead-on-plate welds. From the conditions established for such welds, three sets of conditions were chosen as the best, and these were then used to make a series of butt joints in $\frac{1}{16}$-, $\frac{3}{32}$- and $\frac{1}{8}$-in. thick molybdenum plate. The specific conditions are given in Table 4. All joints discussed in this section were made using straight polarity. These conditions were used with slight modifications where they were deemed necessary.

Table 4—Welding Conditions Chosen for Welding Butt Joints

Arc-voltage setting, v	*Burn-off rate, ipm*	*Approximate current, amp*	*Weld speed, ipm*	*Helium flow, cfh — 1-in. cup*	*Dragging shield*	*Electrode-surface coating*
32	400	400	20	150	150	CsCl
32	325	400	20	150	150	CsCl
32	605	520	25	150	150	None

Each of these conditions produced a different type of weld bead. The first set of conditions deposited a medium amount of filler metal with good penetration. A high, curved bead resulted. The second set of conditions produced a lower bead contour with good penetration, depositing less filler metal. The third set of conditions produced deep penetration and deposited a large amount of filler metal. Under the third set of conditions, the arc was "buried" beneath the plate surface. Emissive electrode coatings did not appear to be required when the arc was buried beneath the sheet surface.

Butt joints were made in $\frac{1}{16}$-in. plate with the following joint designs: (1) square butt joints with $\frac{1}{16}$-in. gap, and (2) single-vee joints with 30-, 60- and 90-deg included angles. One single-vee joint with a 40-deg included angle was made in $\frac{3}{32}$-in. plate and a single-vee joint with a 40-deg included angle with a "U"-groove at the root was made in $\frac{1}{8}$-in. plate. All joints had a small land at the root of the weld.

These initial tests using butt joints indicated that welding conditions established for bead-on-plate welds were not directly applicable to the welding of butt joints. Studies of various joint designs would probably be required to choose the proper joint for each thickness of sheet or plate, and for various welding conditions. The brief study of butt joints indicated that 0.040-in. diam wire could be used for welding joints in $\frac{1}{16}$- and $\frac{1}{8}$-in. plate, and wire $\frac{1}{16}$-in. or larger diameter would be required for $\frac{3}{32}$- and $\frac{1}{4}$-in. thick plate.

Comparison of Weldments

Two welds were made in $\frac{1}{16}$-in. thick molybdenum to compare the inert-gas-shielded tungsten-arc and the consumable-electrode welding processes. The conditions used to make these welds are given in Table 5. It was thought that a fine weld-grain size would result from the consumable-electrode welding of molybdenum, thus increasing the ductility of the weldments as well as the tolerance for impurities.

The weld macrostructures can be seen in Figs. 3 and 4 for bead-on-plate type welds made in $\frac{1}{16}$-in. thick sheet. These photographs indicate that the weld-grain size is about the same for both welds. The grains in the consumable-electrode weld appear to be somewhat more columnar than those in the tungsten-arc weld. Penetration was excessive for the consumable-electrode weld. Possibly if less filler metal had been added by using less current, a finer weld-grain size would have resulted. The heat-affected zone was much broader for the consumable-electrode weld. This could be due to the excessive penetration or to the fact that the weld was not cooled by copper plates as was the case with the tungsten-arc weld.

The microstructures were very similar for the two welds. Figure 5 shows the microstructure for the consumable-electrode weld. The precipitate appearing in the grains and along the grain boundaries has been identified as molybdenum carbide.

The welds were ground flush, stress relieved 1 hr at 1800° F in helium, and sectioned for bend testing. The sheet was also stress relieved and bend tested.

Table 5—Welding Conditions for Comparison of Weldments

Weld	*Process*	*Weld pass*	*Current, amp*	*Arc voltage*	*Helium flow, cfh — Cup*	*Dragging shield*	*Backing*	*Cup diameter, in.*	*Weld speed, ipm*	*Electrode burn-off rate, ipm*	*Electrode diameter, in.*	*Emissive coatings*
C29-6*	Consumable electrode	1	470	32	150	150	†	1	20	605	0.040	None
C29-8‡	Tungsten arc	1	425	18.5	40	150	30	$\frac{3}{4}$	12		$\frac{1}{8}$	§
C30-5**	Consumable electrode	1	470	30	150	150	†	1	20	400	0.040	CsCl
		2	440	30	150	150	†	1	20	325	0.040	CsCl

* Penetration was excessive.
† No gas backing. A $\frac{1}{16}$-in. thick molybdenum backing strip was used to prevent copper pickup.
‡ Made in copper jig with gas backing. Better cooling of weld.
§ Pointed thoriated-tungsten electrode used.
** Single-vee joint, 60-deg included angle.

Table 6—Room-Temperature Bend-Test Data for $^1/_8$-in. Molybdenum Sheet and Weldments

Identification	*Carbon content, %*	*Welding process*	*Permanent bend angle after fracture at 25° C*
Sheet C29[a, b]	0.011	.....	19, 16, 25, 34, 30, 35
Sheet C3[c, d, e]	0.011	.....	50, 85, 90NF[f]
Weld C29-6[a, b]	0.011	Consumable electrode[g]	2, 2, 2, 2, 4, 4, 4
Weld C29-8[a, c]	0.011	Tungsten arc[g]	2, 2, 4, 4, 4, 4, 4
Weld C3[c, d, e]	0.011	Tungsten arc[h]	6, 8, 18

[a] Stress relieved 1 hr at 1800° F in helium.
[b] Bend tested longitudinal to the rolling direction.
[c] Stress relieved 1 hr at 1800° F in hydrogen.
[d] Bend tested transverse to the rolling direction.
[e] From previous study.[3]
[f] NF = no fracture.
[g] Made with dragging shield.
[h] Made in high-purity dry-box atmosphere.

The bend-test data are given in Table 6. These data indicate no difference in ductility between the two welds. Sheet and weldment ductility were poor compared with the ductility of sheet used in previous welding studies (Sheet C3 in Table 6). Sheet C29 was tested with the bend line perpendicular to the rolling direction (normally the most ductile direction), while Sheet C3 was tested with the bend line parallel to the rolling direction. In spite of this, the tungsten-arc weld was considerably more ductile in Sheet C3 than in Sheet C29, undoubtedly owing to the better structural quality of the molybdenum in Sheet C3. Definite conclusions concerning the ductility or weld-grain structure of consumable-electrode welds in molybdenum cannot be established using these initial tests.

A two-pass consumable-electrode weldment was sectioned for macroexamination (Fig. 6). This weld was made in $^1/_4$-in. thick molybdenum plate using a single-vee joint with a 60-deg included angle. The weld-metal grains appear to be slightly smaller in this weld than in the weld in $^1/_8$-in. thick sheet (Fig. 4). Grains at the centerline of the weld are oriented perpendicular to the plane of the plate surface. This orientation could cause a lowering of tensile strength in a direction transverse to the welding direction.

From this limited comparison of weldments it appears that the consumable-electrode welding process would be more adaptable to the welding of thick plates of molybdenum. The tungsten-arc process appears better suited to the welding of sheet up to $^1/_8$ in. thick.

Future Studies

A complete evaluation of the inert-gas-shielded consumable-electrode welding process applied to molybdenum should consider more extended studies than reported here in the following areas:

1. The effect of current density on the metal transfer of reverse- and straight-polarity arc stability and metal transfer.
2. The effect of gas mixtures of argon-helium and argon-hydrogen on arc stability and metal transfer.
3. The effect of emissive coatings other than cesium chloride on arc stability and metal transfer.
4. The effect of other variables on arc stability and metal transfer using emissive-coated electrodes.
5. The cause of spatter and methods of eliminating it.
6. The effect of preheat-postheat cycles, other than the heat supplied by the welding arc, on cracking.
7. The role of joint configuration in the quality of butt joints.
8. The relative merits, as evaluated by weldment microstructures and bend-test ductility, of tungsten-arc and consumable-electrode welds in molybdenum, especially in thick plate.

In addition, several areas remain to be studied. These include studies of:

1. Alternating current for welding molybdenum.
2. An auxiliary magnetic field superimposed parallel to the arc to aid arc stability and improve metal transfer.
3. The welding of $^1/_{32}$- and $^1/_{16}$-in. thick sheet with 0.020-in. diam electrodes to determine if the consumable-electrode welding process is adaptable for welding these thicknesses.
4. The effectiveness of the shielding devices used in this study.
5. The effects of changes in arc voltage.

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FATIGUE CHARACTERISTICS OF SINGLE-LAP JOINTS OF AISI 347 BRAZED WITH A NI-CR-SI-B-C ALLOY

Brazed specimens found to exhibit a fatigue endurance limit equivalent to the original annealed AISI 347 strip at room temperature, and about ten percent lower than the unbrazed material at 1100° F

BY R. G. ASPDEN AND W. FEDUSKA

SYNOPSIS. Annealed AISI 347 strip material has been fatigue tested and found to possess an endurance limit, at 50×10^6 cycles, of 31,600 psi at room temperature and 31,000 psi at 1100° F. Single-lap joints of this material, brazed with a Ni-Cr-Si-B-C alloy in a dry hydrogen atmosphere of −60° F dew point, had an endurance limit equivalent to the original annealed AISI 347 strip at room temperature. At 1100° F, however, the brazed specimens exhibited a fatigue endurance limit which was about 10% lower than the unbrazed material. A possible mode for fatigue cracking in these brazed joints is presented.

Introduction

Numerous high-temperature alloys are being used in gas and steam turbines, missiles and nuclear reactors. In this equipment the alloys are found in a variety of intricate shapes and sizes which must often be joined together. The shape and required physical properties of these components may make conventional joining methods, such as welding, either impossible or impractical. To circumvent these difficulties, a new joining method, high-temperature alloy brazing, is being developed. This technique generally involves fusion of nonferrous alloys melting in the temperature range 1800 to 2200° F, which is lower than that of the base metals being joined. One of the advantages of this technique is that numerous components may be bonded in a single operation. In addition, since the high-temperature alloy parts would remain essentially free from fusion in the joint region after the brazing operation, distortion-free assemblies may be produced. Also, postjoining heat treatment would not be required, since relatively little stress would exist in the brazed areas.

To date, mechanical-property data gathered on high-temperature alloy brazed joints consist mainly of tensile- and shear-strength data of furnace brazed joints. Some strength data may be found in the references listed in the bibliography.[1-9] To supplement these data, and to obtain an insight into the effects of dynamic stresses on brazed joint interfaces, fatigue test data have been obtained on AISI 347 joints brazed with a Ni-Cr-Si-B-C alloy.

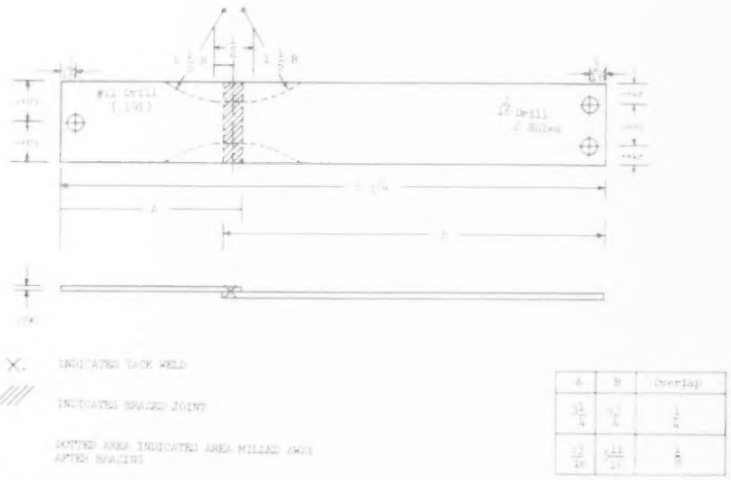

Fig. 1 Single-lap-joint fatigue specimen

Materials

Annealed AISI 347 strip material, 0.090 in. in thickness, was used for both the base metal and the brazed lap-joint fatigue specimens. All of the lap-joint specimens were brazed with a Ni-Cr-Si-B-C brazing alloy that meets the composition requirements for AMS 4775. The nominal composition of this alloy is: 65–75% nickel, 13–20% chromium, 2.75–4.75% boron, and 10% iron plus silicon plus carbon, having 1% maximum carbon.

Component sections of single-lap-joint specimens were machined according to the dimensions given in Fig. 1. The overlap surfaces, which were to be brazed, were then polished to a No. 1 metallographic paper finish, after which the sections were thoroughly degreased and dried with alcohol. Joint overlaps were set at $\frac{1}{4}$ in., (approximately $1\frac{1}{2}$ times longer than the strip thickness) or $\frac{1}{2}$ in. (approximately 3 times longer than the strip thickness) in accordance with minimum design specifications for maximum joint efficiency[10] before the tack welding operation. Each lap-joint specimen was then preadjusted, by tack welding, to insure a joint clearance of about 0.001 in. during brazing.

After the tack-welding operation, the brazing-alloy powder, mixed with calcium chloride and water to form a slurry, was preplaced at the unwelded joint edges and dried. With the joints horizontally positioned, the specimens were furnace brazed at 2060° F in a dry hydrogen atmosphere of −60° F dew point. The brazing cycle consisted of

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Fig. 2 Brazed-lap-joint fatigue specimen (*A*) and base-metal fatigue specimen (*B*)

During testing, single-hole ends of the specimens were stationary, while double-hole ends were flexed

Table 1—Fatigue Test Data of AISI 347 Sheet Material

Sample	Stress, psi	Cycles to failure
Tested at Room Temperature		
B-2	37,750	1.797 × 10⁵
B-3	38,250	1.126 × 10⁵
B-4	34,850	0.937 × 10⁵
B-5	35,050	1.441 × 10⁵
B-7	34,350	3.133 × 10⁵
B-8	35,600	1.455 × 10⁵
B-9	32,450	51.649* × 10⁵
B-10	34,100	2.478 × 10⁵
B-13	33,450	1.893 × 10⁵
B-15	32,250	1.996 × 10⁵
B-16	32,450	2.195 × 10⁵
B-14	32,000	2.996 × 10⁵
B-17	31,500	54.000* × 10⁵
Tested at 593° C (1100° F)		
B-11	29,450	1.580 × 10⁵
B-12	29,000	53.286* × 10⁵
B-18	29,500	50.000* × 10⁵
B-19	32,150	1.562 × 10⁵
B-20	30,000	47.030* × 10⁵
B-23	31,000	29.036* × 10⁵
B-24	34,050	0.088 × 10⁵
B-25	32,750	0.324 × 10⁵
B-26	32,100	0.430 × 10⁵
B-27	32,050	0.039 × 10⁵
B-29	31,000	16.345* × 10⁵

* Specimen did not fail.

Table 2—Fatigue Test Data of AISI 347 Single-Lap Joints Brazed with Ni-Cr-Si-B-C Alloy

Sample no.	Stress, psi	Cycles to failure	Measured joint thickness, in.
1/8-in. brazed overlap—room temperature			
11	35,700	0.969 × 10⁵	0.003
12	36,700	1.869 × 10⁵	0.001
13	33,000	4.126 × 10⁵	0.001
14	32,000	10.079* × 10⁵	0.001
15	33,000	1.928 × 10⁵	0.001
16	32,550	12.862 × 10⁵	0.001
10	37,600	0.383 × 10⁵	0.001
20	33,300	7.191 × 10⁵	0.001
21	34,000	1.333 × 10⁵	0.001
22	32,400	50.004* × 10⁵	0.001
1/8-in. brazed overlap—593° C (1100° F)			
A-1	33,850	0.023 × 10⁵	
A-5	28,700	0.065 × 10⁵	
A-6	27,000	10.650* × 10⁵	
A-7	28,150	0.113 × 10⁵	
A-8	27,350	0.254 × 10⁵	
1/4-in. brazed overlap—593° C (1100° F)			
A-15	28,000	24.676* × 10⁵	
A-16	28,250	0.140 × 10⁵	
A-17	28,000	10.600* × 10⁵	
A-18	29,000	34.700* × 10⁵	
A-19	28,100	33.848 × 10⁵	
A-20	30,550	0.084 × 10⁵	

* Specimen did not fail.

thirty minutes heating time and ten minutes brazing time, followed by furnace cooling from the brazing temperature. After the brazing operation, the tack welds were milled off the overlap region, thereby completing the preparation of the brazed fatigue specimens. Samples of plain and brazed fatigue specimens are shown in Fig. 2.

Both the brazed and unbrazed fatigue specimens were tested on an SF-2 fatigue machine. This machine can supply completely reversed bending loads to a specimen at a constant speed of 1800 cycles per min. Testing was conducted both at room temperature and at 1100° F for the unbrazed specimens and the brazed, 1/8-in. overlap specimens. The brazed 1/4-in. overlap specimens were tested only at 1100° F.

When the fatigue endurance limits, under the various test conditions, had been determined for a life of 50×10^5 cycles, an additional specimen was tested at a higher stress level to nearly 100% of its estimated fatigue life at room temperature. This specimen was then longitudinally sectioned at five positions through the brazed-joint interface and examined microscopically for incipient fatigue cracking.

Results and Discussion

The results of all of the fatigue tests are presented in Tables 1 and 2 and Figs. 3 and 4. All fatigue failures occurred at the edges of the brazing-alloy fillets. These failures were on the stationary leg of the specimens, in the vicinity of maximum change in stress for the brazed region (Fig. 5). Their location was largely dependent on the length of the brazing-alloy fillet. The failures appeared near the edge of the joint-overlap region when little filleting occurred, or at the edge of the fillet extending away from the joint when heavier filleting occurred (Fig. 6). No fatigue failures appeared in the brazed-joint interface regions of any of these test specimens.

For the various test series, the fatigue endurance limits were found to be as follows:

Specimen condition	Endurance limit at 50×10^5 cycles: Room temperature	(1100° F)
Unbrazed	31,600 psi	31,000 psi
Brazed, 1/8-in. overlap (1 1/2 t), 0.001-in. joint	32,400 psi	27,000 psi
Brazed, 1/4-in. overlap (3 t), 0.001-in. joint		28,000 psi

As indicated by these data, the fatigue strength of a single-lap joint of AISI 347, brazed with a Ni-Cr-Si-B-C alloy, was

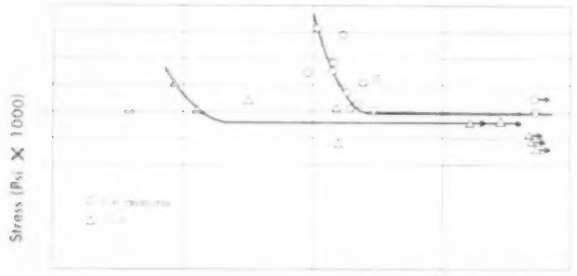

Fig. 3 The effect of temperature on the fatigue strength of AISI 347 stainless-steel sheet

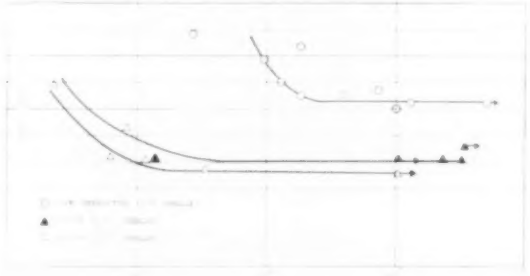

Fig. 4 The effect of temperature and joint overlap on the fatigue strength of single-lap joints of AISI 347, brazed with Ni-Cr-Si-B-C alloy

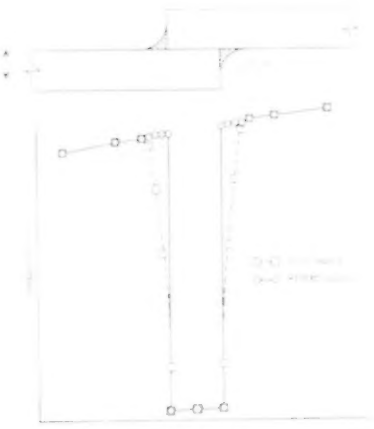

Fig. 5 Nature of stress distribution along the length of a brazed-single-lap-joint specimen

Stress concentration in the fillet region is not shown

equivalent to the unbrazed base metal at room temperature. At 1100° F, the fatigue strength of the base metal was virtually unchanged, while the fatigue strengths of the brazed joints decreased about 10% to equivalent, lower levels for both the $\frac{1}{8}$- and $\frac{1}{4}$-in. overlap specimens. This decrease in the fatigue strength of the brazed specimens might be attributed to hot-shortness, either of the boron-compound or boron-rich solid solution which was produced when boron from the brazing alloy penetrated into the grain boundaries of the base metal.

Considerable grain-boundary penetration, primarily by the boron of the brazing alloy, was observed in the base metal of the brazed specimens. For each joint, the penetration was heavy at the joint-interface region and decreased uniformly toward the edges of the brazing-alloy fillets. This occurred because the total amount of boron available for diffusion decreased as the amount of brazing alloy decreased, from a maximum at the interface to a minimum at the leading edge of the fillet (Figs. 7 and 8). The apparent difference in the amount of boron penetration shown in Figs. 7 and 8 is due to the difference in magnification.

To determine the origin of fatigue cracking in these joints, a brazed specimen was tested at room temperature to almost 100% of its estimated fatigue life at a selected stress level above its endurance limit. Using the data previously obtained, this specimen was cycled at ±34,000 psi for 1,414,000 cycles before being removed from the fatigue machine. An ensuing examination of five transverse sections through the brazed-joint interface of the sample revealed a transcrystalline fatigue crack in one section, near the edge of the brazing-alloy fillet (Fig. 9). From the microstructural nature of this crack, the following mechanism is suggested for fatigue cracking of single-lap joints of Type 347 material, brazed with an Ni-Cr-Si-B-C alloy and subjected to flexural loading.

Since the base-metal surface grains at the interface region between the brazing alloy and the base metal would be subjected to the highest stress, localized slip would be expected to occur preferentially in this region. Initially, localized slip must have occurred, under the action of the cyclic stressing, in surface grains of the base metal which were preferentially oriented to the applied stress. This slip would be produced by a migration of dislocations within these grains to the grain-boundary regions. Here, the dislocations would pile up in groups at the barrier produced by the brittle, grain-boundary constituent (which would be formed when boron from the brazing alloy penetrated into the grain boundaries of the base metal). At some grain-boundary location, within this area, the dislocations would be piled-up to such an extent that the concentrated stress produced by the pile-up would exceed the cohesive strength either of the brittle grain boundary or of the adjacent grain material, and would initiate a microcrack in the weaker constituent. The root of the microcrack would serve as a region of high stress concentration and would initiate a transcrystalline fatigue crack in the base metal. As the fatigue cracking progressed, the ultimate strength of the ductile, low-melting constituent of the brazing alloy in the fillet region above the crack would be exceeded. The fillet metal would then fail, by the shearing action observed in Fig. 9 and also in Fig. 8. Thereafter, fatigue cracking would progress until the cross-sectional area of the sound section would decrease to a critical amount. Then the ultimate strength of the uncracked material would be exceeded and the remaining cross section would fail instantaneously.

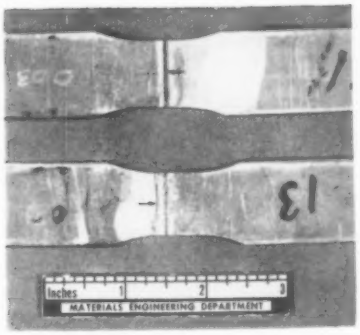

Fig. 6 Nature of fatigue cracking in single-lap joints of AISI 347, brazed with Ni-Cr-Si-B-C alloy

Arrows indicate cracking either at edge of the overlap, when little filleting occurred (*top*), or at the edge of the fillet, extending out from the overlap region, when heavy filleting occurred (*bottom*).

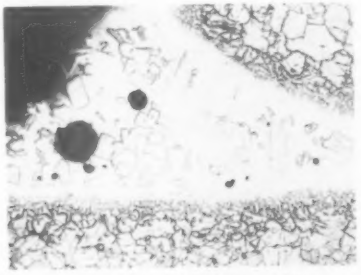

Fig. 7 Ni-Cr-Si-B-C alloy fillet on AISI 347 lap joint. X250

Note boron diffusion into AISI 347 grain boundaries has resulted in the formation of a hard boron-compound network.

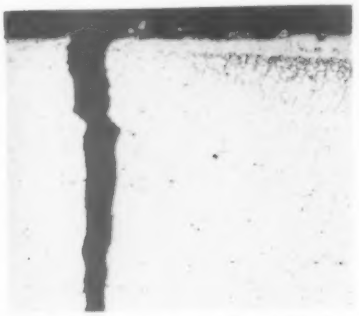

Fig. 8 Gradient grain-boundary penetration effect. X100

Note transcrystalline fatigue crack near the edge of the Ni-Cr-Si-B-C alloy as well as the boron-compound network in the grain boundaries of the AISI 347 material.

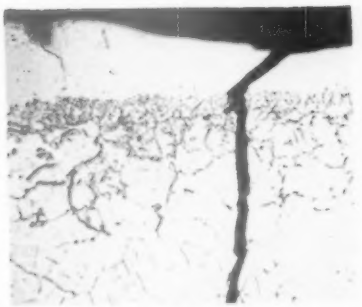

Fig. 9 Incipient fatigue crack in AISI 347 fatigue specimen brazed with Ni-Cr-Si-B-C alloy and cycled to nearly 100% of its approximate endurance limit. X1000

Note the transcrystalline crack in the base metal and the shear crack in the brazing alloy of the fillet.

Summary

1. The fatigue endurance limits at 50×10^6 cycles of single-lap joints of

annealed AISI 347, when furnace brazed with an Ni-Cr-Si-B-C alloy in dry hydrogen, were found to be as follows:

Specimen condition	*Room temperature*	*1000° F*
AISI 347 base metal	31,600 psi	31,000 psi
AISI 347 brazed with 1½ t overlap	32,400 psi	27,000 psi
AISI 347 brazed with 3t overlap		28,000 psi

2. Fatigue cracking in the flexed, single-lap joint specimens occurred near the location of maximum change in stress in the region immediately adjacent to the joint, rather than through the joint interface.

3. A mechanism for fatigue cracking of flexed, single-lap joints of AISI 347, brazed with an Ni-Cr-Si-B-C alloy, was presented. The concentration of stress, produced by the pile-up of dislocations at grain-boundary barriers in the region of localized slip created a microcrack in this vicinity, either in the adjacent grain material or in the brittle grain-boundary constituent which had formed at the joint interface during brazing. This microcrack then propagated as a transcrystalline fatigue crack through the test specimen.

Acknowledgment

The authors express their thanks to Messrs. Heuschkel and Wessel, of the Research Laboratories of Westinghouse Electric Corp., for their discussions related to cracking of AISI 347 materials. Further thanks is extended to Mr. Zibritosky of the Physical Testing Laboratories of the Materials Engineering Department of Westinghouse Electric Corp. for determining the nature of the stress distribution in the brazed fatigue specimens.

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THE EFFECT OF DEFECTS ON THE FATIGUE STRENGTH OF SUBMERGED-ARC WELDS

(Continued from p. 113-s.)

Table 1—Composition, Tensile Properties and Fatigue Results for Pressure Vessel Steels

Type of defect	*Steel*	*Plate thickness, in.*	*C*	*Si*	*Mn*	*Cr*	*Cu*	*Ni*	*Others*	*Yield strength, psi*	*Tensile strength, psi*	*Number of stress steps before failure*
None	H I H	1 14	0 21	0 23	0 70					46,200	69,200	5
None	432M	2 48	0 22	0 49	1 20					51,300	78,900	>3
None	H III	2 01	0 18	0 23	0 71					44,400	67,000	>3
None	19 Mn 5	1 69	0 17	0 55	1 06					53,000	78,400	>3
None	CuNi52	3 54	0 16	0 40	1 04	0 12	1 04	0 98		54,400	76,300	4
Incomplete fusion	426M	2 48	0 15	0 31	1 02					45,500	67,500	1
Incomplete fusion	H H	1 18	0 16	0 25	0 54					38,500	62,800	1 or 2
Porosity and slag inclusions	426 M	2 05	0 15	0 28	1 00					44,000	70,000	2
Porosity and slag inclusions	19 Mn 5	2 67	0 19	0 39	1 10		0 18		0 22Al	48,600	77,400	4
Porosity and slag inclusions	CuNi52	3 54	0 16	0 40	1 04	0 12	1 04	0 98		54,400	76,300	4
Porosity and slag inclusions	H III	1 14	0 21	0 23	0 70					46,400	69,400	3
Porosity and slag inclusions	H III	2 01	0 18	0 23	0 71					44,400	67,000	3
Porosity and slag inclusions	H H	1 10	0 13	0 15	0 59					43,500	66,900	3
Porosity and slag inclusions	19 Mn 5	1 69	0 17	0 55	1 06					53,000	78,400	>3
Reverse welded (no defects)	CuNi 47	3 15	0 15	0 45	0 72	0 23	0 82	0 92	<0 001Al	48,600	70,000	2
Reverse welded (no defects)	St 47	2 67	0 22	0 22	0 93					42,300	77,000	4
Reverse welded (no defects)	CuNi47	3 15	0 15	0 37	0 66	0 29	0 86	0 97	0 011Al	58,500	78,500	5
Laminated plate	CuNiMo52	3 61	0 15	0 39	0 97	0 39	1 07	0 87	0 34Mo	64,200	93,000	5 or 6
Laminated plate	CuNi 52	3 94	0 15	0 44	1 11	0 28	0 94	0 85		58,600	82,600	4

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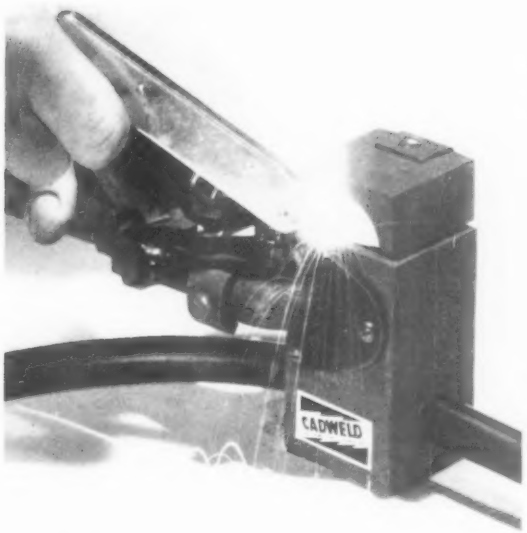
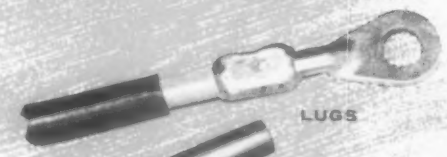


GROUND CLAMPS



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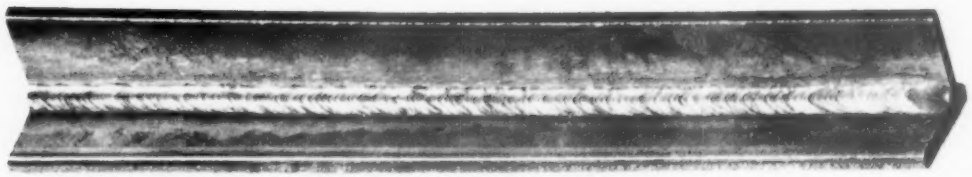

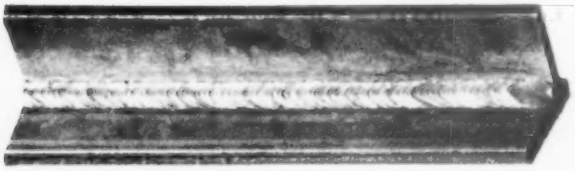

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